THE

SOUTH AFRICAN JOURNAL OF SCIENCE

VOLUME XXXV

BEING THE

REPORT

OF THE

THIRTY-SIXTH ANNUAL MEETING

OF THE

SOUTH AFRICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

PIETERMARITZBURG

1938

4 JULY to 9 JULY

JOHANNESBURG
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and
Printed by RADFORD, ADLINGTON, LTD, Rissik and Marshall Streets

1938

Form of Application for Membership.

To the Assistant General Secretary,

South African Association
for the Advancement of Science,
P.O. Box 6894, Johannesburg.

I desire to become *.............................. member of the South African Association for the Advancement of Science, and for this purpose I enclose a Cheque for £...........................†

1. Name in full ....

2. Academic Degrees or Diplomas, Fellowships of Learned Societies, etc., held (if any) ....

   ....

3. Profession or Occupation ....

4. Full Postal Address ....

5. Signature ....

Date ....

---

* Please state whether "Ordinary Member," "Life Member," or "Associate Member." Subscriptions are as follows: Life Members, £15; after ten consecutive years as an Ordinary Member, £7 10s. Ordinary Members, £1 10s. per annum. Associate Members, £1, for period of the Annual Session only. Student Members (not exceeding 23 years), 10s. 6d. for period of Annual Session only. (Associate and Student Members are not entitled to receive the Journal of the Association.)‡

Candidates resident in the Witwatersrand (Randfontein to Springs) should add the sum of £1 1s. for membership of the Associated Scientific and Technical Societies of South Africa.

† Cheques, etc., should be crossed and made payable to the Assistant General Secretary, South African Association for the Advancement of Science, and 6d. should be added to country cheques to cover exchange.

‡ Student members will be supplied with the Journal at the reduced price of 10s.; application for this privilege must be countersigned by the Head of the University Department in which the student is working.

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BEING THE REPORT OF THE

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(1938, PIETERMARITZBURG)

Vol. XXXV | JULY, 1938. | Vol XXXV

EDITORIAL NOTE

It is my sad duty to refer to the death on 26th October, 1937, in Montreal, of a distinguished former Honorary Editor of Publications, Professor H. B. Fantham. Professor Fantham devoted much time, energy and ability to the editing of the *South African Journal of Science*, and was responsible for bringing about for it both a greatly enhanced standard and a wider distribution.

I have to explain the late appearance of the JOURNAL as being partly the outcome of the decision of the Council, acting upon a recommendation by the Publications Committee, that there should be a particularly careful consideration of the Association's policy respecting the publication of papers presented at the Annual Session. Such consideration by a special Committee, by selected referees, by most of the authors of papers, and ultimately by the Council, naturally has entailed delay in setting the printers to work—it was late September before a beginning could be made. It is my duty to thank Members of the Publications Committee for their aid and support, and to express appreciation of the Committee and the Council for the splendid spirit of co-operation shown by authors so far as withdrawal, reduction or modification of their papers were concerned. Such whole-hearted and kindly co-operation has resulted in a JOURNAL of reasonable dimensions being published with a minimum of trouble and irritation to all concerned.

For purposes of economy, the Business section of the current volume has been very greatly reduced.

In connection with presentation of papers at the forthcoming Annual Session, the Council asks that contributors do their utmost to keep their papers within reasonable limits, attempt to present carefully condensed summaries in the place of lengthy detailed descriptions and reduce the number of illustrations for publication to a minimum.

For preparation of the Index in volumes XXXIV and XXXV I am am deeply indebted to Mr. S. B. Asher.

To Mr. I. Hume, Botanical Department, University of the Witwatersrand, I owe thanks for much assistance in the details of editing.

John Phillips

December, 1938. Hon. Editor of Publications.

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PROCEEDINGS OF THE THIRTY-SIXTH ANNUAL GENERAL MEETING OF MEMBERS, HELD AT THE NATAL UNIVERSITY COLLEGE, PIETERMARITZBURG, ON FRIDAY, 8TH JULY, 1938. 32 10 A.M.

PRESENT: Professor L. F. Maingard (President) in the Chair, Mr. S. B. Asher, Mr. C. E. Axelson, Dr. A. W. Bayer, Mr. B. P. Bates, Mrs. H. Boehmke, Dr. M. Boehmke, Mr. F. G. Braithwaite, Mrs. M. H. Bush, Dr. S. F. Bush, Mr. P. Cazalet, Mr. E. C. Chubb, Professor Hugh Clark, Mr. J. R. H. Coutts, Mr. H. H. Dodds, Mrs. H. H. Dodds, Dr. A. L. du Toit, Miss F. Eddy, Miss B. S. Fisher. Mr. S. M. Flanagan, Miss D. M. Gemmell, Mrs. M. G. Gemmell, Mr. J. H. Gilchrist, Dr. J. Gillman, Mr. Jas. Gray (Hon. General Treasurer). Mr. E. M. Grieve, Mr. T. D. Hall, Dr. J. S. Henkel, Miss M. Henrici, Miss J. Henshel, Mr. G. A. Hepburn, Dr. A. J. Hesse, Mr. H. J. Jaffe. Dr. C. F. Juritz (Hon. General Secretary), Dr. L. C. King, Professor P. R. Kirby, Hon. Justice F. E. T. Krause, Mr. A. J. Limebeer, Mr. N. M. Lindsay, Professor C. van Riet Lowe, Miss A. Lyle, Professor I. D. MacCrone, Dr. A. MacMartin, Mrs. A. M. Maingard, Mr. D. Meredith, Dr. M. G. Mes, Mr. D. L. Niddrie, Professor John Orr. Professor H. H. Paine, Mr. J. E. L. Peck, Mr. B. K. Petty, Dr. E. P. Phillips, Professor John Phillips, Miss H. P. Pollak, Mr. G. Riemerschmid, Mr. D. M. Rice, Professor M. M. Rindl, Dr. J. B. Robertson. Professor N. J. G. Smith, Mr. A. J. Taylor, Professor Gertrud Theiler. Dr. E. C. N. van Hoepen, Dr. L. H. Wells, Miss E. E. Wijers, Mr. J. Young, and Mr. H. A. G. Jeffreys (Assistant General Secretary).

Apologies for absence were received from Professor R. A. Dart. Professor C. G. S. de Villiers, Dr. A. Galloway, the Hon. J. H. Hofmeyr, and Mr. J. H. Power.

MINUTES.—The Minutes of the Thirty-fifth Annual General Meeting, held at Windhoek on the 8th July, 1937, and printed on pages xxii-xxiv of the Report of the Windhoek Session (Volume XXXIV of the JOURNAL), were confirmed.

ANNUAL REPORT OF COUNCIL.—The Annual Report of the Council for the year 1937-1938, having been duly suspended on the notice board at the Natal University College, was taken as read and adopted. This Report will be found on pp. vii-viii of this issue.

REPORT OF THE HONORARY GENERAL TREASURER AND STATEMENT OF ACCOUNTS.—The Honorary General Treasurer's Report and Statement of Accounts for the year ended 31st May, 1938, having been duly suspended on the notice board at the Natal University College, were taken as read and adopted. (See pp. ix-xv of this issue).

ELECTION OF OFFICERS FOR 1938-1939.—The following were elected

President: Professor G. H. Stanley.

Vice-Presidents: Professor R. A. Dart.
Col. J. G. Rose
Dr. S. F. Bush.
Dr. E. C. N. van Hoepen.

Hon. General Secretaries: Dr. C. F. Juritz and Dr. H. E. Wood.

Hon. General Treasurer: Jas. Gray.

Hon. Editor of Publications: Professor John Phillips.

Hon. Librarian: P. Freer.

COUNCIL MEMBERS.—The following were elected:—

I. TRANSVAAL.—J. T. Allen, S. B. Asher, R. Craib, Dr. A. L. du Toit, Dr. A. Galloway, Dr. J. Gillman, T. D. Hall, Dr. E. J. Hamlin, Professor P. R. Kirby, A. J. Limebeer, Professor C. van Riet Lowe,

Professor I. D. MacCrone, Professor John Orr, Professor H. H. Paine, F. R. Paver, Miss H. P. Pollak, Dr. J. B. Robertson, Professor B. F. J. Schonland, Dr. B. Segal, Professor P. J. du Toit, Dr. R. A. Dyer, Professor J. M. Hector, Dr. H. O. Monnig, Dr. E. P. Phillips, Dr. A. Pijper, Dr. E. M. Robinson Professor P. Goosens.

II. CAPE OF GOOD HOPE PROVINCE.—Dr. L. D. Boonstra, Dr. A. J. Hesse, G. W. Lyon, Dr. B. de C. Marchand, Dr. S. H. Skaife, Dr. C. von Bonde, Professor Gertrud Theiler, Professor L. Verwoerd, F. J. S. Anders, J. H. Power, Dr. M. Boehmke, Professor N. J. G. Smith, H. C. Gardham.

III. ORANGE FREE STATE.—Dr. A. C. Hoffman, Professor W. H. Logeman.

IV. NATAL.—Principal J. W. Bews, F. G. Braithwaite, E. C. Chubb, H. H. Dodds, Dr. John Fisher, J. F. Schofield.

V. SOUTHERN RHODESIA.—Rev. N. Jones, H. B. Maufe.

ANNUAL MEETING, 1939.—The invitation of the City Council of East London for the Association to hold its Annual Session in that city in 1939 was accepted unanimously and enthusiastically.

PRESERVATION OF THE RED HARTEBEEST.—The following resolution, proposed by Dr. R. P. Lawrence and seconded by Mr. E. C. Chubb, was carried unanimously:—"The South African Association for the Advancement of Science strongly urges the Natal Provincial Executive to take steps without further delay for the preservation of the sole surviving remnant of the typical race of the Red Hartebeest (*Bubalis caama*) at present existing on the farm Moe's Rest in the New Hanover District of Natal. Since these animals are the sole survivors of the typical race of the species, formerly distributed over the northern, eastern and central districts of South Africa, and which is distinct from the race still surviving in the Kalahari region, their claims to preservation in the interests of science and humanity are as important as those of the Bontebok and Mountain Zebra which have already been protected by the Union Government."

SOLAR RADIATION.—The following resolution, proposed by Professor F. E. Plummer and seconded by Professor H. Clark, was carried unanimously:—"This Association appreciates the significance of the investigation being conducted into Solar Radiation in the Union of South Africa; but feels that the study is too meagre and should be intensively prosecuted by a close collaboration of investigators in the biological and pure sciences, as the information is indespensible to the welfare of the community."

COMMITTEE ON SCIENCE AND SOCIAL RELATIONS.—It was reported that the above Committee had been approached with a view to co-operation. The questionnaires supplied were being circulated to persons concerned and a Committee of the Association had been formed consisting of Professor L. F. Maingard, Professor John Phillips, Professor B. F. J. Schonland. Dr. van den Bos with Mr. H. B. Gilliland as Secretary.

MEMBERSHIP.—The following resolution, proposed by Dr. R. H. Marloth, was referred to Council:—"That the Council of the Association devise and exploit ways and means whereby the ordinary and institutional membership of the South African Association for the Advancement of Science be markedly increased.

SYMPOSIUM: THE NEED FOR THE CONSERVATION OF SOUTH AFRICA'S NATURAL RESOURCES AND FEATURES OF SCIENTIFIC INTEREST AND IMPORTANCE.—The Meeting was of opinion that the Symposium had been successful and recommended that a Symposium be held next year. The following resolution, proposed by Professor A. P. Goosens and seconded by Mr. T. D. Hall was referred to Council:—"That the Council con-

sider the advisability and possibility of publishing these contributions as a separate copy or reprint forming the first of a series of highly educational subjects, so that teachers and those interested could have an opportunity of obtaining it."

Dr. A. L. du Toit also moved the following resolution, which was referred to Council:—"That the South African Association for the Advancement of Science, viewing with concern the general wastage in South Africa's natural resources, with special reference to her soils, vegetation, and features of archaeological and ethnological interest, desire respectfully to draw the attention of the Prime Minister to the attached report of a Symposium held in Plenary Session entitled 'The Need for the Conservation of South Africa's Natural Resources and Features of Scientific Interest and Importance.' The Association respectfully requests that the Prime Minister afford a meeting with representatives of the Association, who would place before him proposals covering possible means of more effectively combating the wastage described in the report."

South African Teachers' Association.—Dr. M. Boehmke conveyed to the Meeting the kindly greetings and good wishes of the Association.

Votes of Thanks.—On the motion of Professor John Orr it was agreed unanimously that the thanks of the Association be accorded to the following:—

To His Worship the Mayor (Councillor F. J. Lewis), the City Council, the Mayoress and the members of the Local and Reception Committees, for the excellent arrangements for the Meeting.

To the members of the Ladies' Sub-committee for the arrangements for morning and afternoon teas.

To the Principal of the Natal University College (Professor J. W. Bews) for the use of the College buildings.

To the ladies and gentlemen who kindly provided transport for the excursions.

For hospitality on excursions:

To the Principal, Cedara School of Agriculture.

The Officer-in-charge, Allerton Veterinary Laboratory.

Councillor Mrs. E. M. Russell and the Manager, Municipal Native Administration Department.

Mrs. Pope Ellis.

The Manager, Messrs. Eddels (S.A.), Ltd.

The Manager, Sutherlands Tannery.

The Manager, S.A. Rubber Manufacturing Co., Ltd., Howick.

Mr. French, Pietermaritzburg.

To the Natal Provincial Authorities and to Capt. Potter, Game Conservator, for facilities to visit and hospitality in the Hluhluwe and St. Lucia Game Reserves.

To the S.A. Broadcasting Corporation (Durban and Pietermaritzburg Stations) for facilities for broadcasting daily summaries of the Sessional programme.

For privileges of honorary membership during the Session:

To the Maritzburg Women's Club.

The Victoria Club.

The Maritzburg Golf Club.

The Maritzburg Country Club.

The Maritzburg Bowling Club.

The Victoria Bowling Club.

The Woodburn Bowling Club.

The Natal University College Tennis Club.

For hospitality:

To the Pietermaritzburg Rotary Club; and to the Pietermaritzburg Archaeological Society and the Director, Natal Museum.

To the Press for their services in reporting papers read at the Meeting.

To Dr. S. F. Bush, Honorary Secretary of the Local Committee, for his valuable services in connection with the arrangements for the Meeting.

Continuing, Professor Orr proposed a hearty vote of thanks to the retiring President, Dr. Maingard, whose unfailing tact and courtesy had contributed greatly to the success of the Meeting. He had always been ready to perform whatever duty was allocated to him. He had undertaken to give the address to the Rotary Club and had summed up the discussions in connection with the symposium in a masterly manner. Previous meetings had been held at Maritzburg in 1907 and 1916, at both of which he (Professor Orr) had been present, and, speaking as a foundation member of the Association, he considered that the present meeting would go down as one of the most sucessful, both as regards number of members attending and the quality of the papers, which had yet been held.

He also asked that the thanks of the Association be accorded to Dr. C. F. Juritz and Dr. H. E. Wood, who had for so many years acted as Joint Honorary Secretaries; to Mr. James Gray who controlled the finances of the Association, sometimes with an iron hand; to Professor John Phillips, the Honorary Editor of Publications who assisted the Association in many other capacities; to Mr. P. Freer, the Honorary Librarian; and to Captain H. A. G. Jeffreys who for so many years had been the Assistant General Secretary.

The votes of thanks were recorded with acclamation.

REPORT OF COUNCIL FOR THE YEAR ENDED 30TH JUNE, 1938.

1. OBITUARY.—Your Council has to report the deaths of the following members:—Dr. H. D. Anders, Mr. R. H. Blakeley, Mr. G. S. Burt Andrews (Life Member), Professor J. E. Duerden (Honorary Life Member, President of the Association, 1921), Mr. F. Eyles, Professor H. B. Fantham (Life Member, President of the Association, 1927, South Africa Medallist, 1931), Rev. J. D. H. Hepburn, Mr. H. Judson, Mr. Charles Maggs, Advocate H. B. Papenfus (Life Member), Senator Dr. A. W. Roberts (Foundation Member, President of the Association, 1913, South Africa Medallist, 1912), Dr. D. H. Wessels, Miss F. M. White (Foundation and Life Member), Mr. James Wood (Life Member).

2. MEMBERSHIP.—Since the last Report forty-three members have joined the Association, fourteen have died and eighteen have resigned. The net increase of membership, therefore, has been eleven. The following comparative table, as from 1st July, last year, shows the geographical distribution of membership:—

	1937.	1938.
Transvaal	362	369
Cape of Good Hope	218	216
Natal	78	86
Orange Free State	32	33
Southern and Northern Rhodesia	15	14
South-West Africa	3	3
Moçambique	6	6
Abroad	26	24
	740	751

3. THE JOURNAL.—Volume XXXIV of the *South African Journal of Science*, comprising the Report of the Windhoek Meeting, consisted of 510 pages and numerous plates and text figures. It was published in November, 1937.

4. SOUTH AFRICA MEDAL AND GRANT, 1938.—On the recommendation of the South Africa Medal Committee, consisting of Dr. H. E. Wood (Chairman), Principal J. W. Bews, Dr. R. Broom, Professor C. G. S. de Villiers, Professor A. L. du Toit, Professor P. J. du Toit, Dr. A. C. Hoffman, Professor I. D. MacCrone, Professor L. F. Maingard, Dr. E. P. Phillips, Professor M. M. Rindl and Col. J. G. Rose, your Council have awarded the South Africa Medal, together with a Grant of £54 3s. 6d., to Professor P. R. Kirby, M.A., D.Litt., F.R.C.M., F.R.S.E. The Secretary of the British Association has been notified of the award.

5. BRITISH ASSOCIATION MEDAL.—The sixth award of the British Association Medal has been made to Dr. L. H. Wells for his paper on "The Status of the Bushmen as revealed by the Study of Endocranial Casts."

6. DONATIONS.—The thanks of the Association are due to the Honourable the Minister of Mines, Education, Labour and Social Welfare for a Grant of £250 towards the cost of the publication of the JOURNAL, and to the Municipal Council of the City of Johannesburg for a Grant of £100 for a similar purpose.

7. XV INTERNATIONAL CONGRESS OF OPTHALMOLOGY.—The Association was invited to appoint a delegate to this Congress which was held at Cairo in December, 1937. Dr. Alexander Jokl was appointed to represent the Association.

8. INTERNATIONAL ASSOCIATION OF MICROBIOLOGISTS.—This Association had suggested, in correspondence with Sir Spencer Lister, that arrangements might be made for South African representation. Sir Spencer Lister had proposed that the South African Association should act in that capacity and your Council appointed Sir Spencer to represent the Association.

9. COMMITTEE OF SCIENCE AND SOCIAL RELATIONS, DELFT, HOLLAND.—The Association has been invited to co-operate with the above Committee and the matter has been left in the hands of the President and Honorary Editor for report to Council.

10. QUARTERLY BULLETINS.—Three Bulletins have been issued during the year under review, viz., in January, March and June, 1938.

11. THE NEW COUNCIL.—On the basis of membership provided in the Constitution, Section 22, the number of members of Council assigned for the representation of each Centre during the ensuing twelve months should be distributed as follows:—

Transvaal—	
Witwatersrand	19
Pretoria	7
Outside	1
Cape of Good Hope Province—	
Cape Peninsula and outside	6
Stellenbosch and District	3
East London and Port Elizabeth	1
Grahamstown, Kingwilliamstown and District	1
Kimberley	1
Oudtshoorn	1
Natal—	
Pietermaritzburg and Durban	4
Outside	1
Orange Free State—	
Bloemfontein	2
Southern Rhodesia	2
Moçambique	1
	50

The Council wishes to place on record its appreciation of the valuable services and effective assistance rendered throughout the year by the Assistant General Secretary, Mr. H. A. G. Jeffreys, O.B.E.

REPORT OF THE HONORARY GENERAL TREASURER FOR THE YEAR ENDED 31st MAY, 1938.

The financial position this year is more satisfactory than it has been for some time past, the excess of revenue over expenditure amounting to £160 10s. 5d. This is due chiefly to a decrease in the size of the JOURNAL and consequent reduction in the cost of printing. The expenditure is lower in many directions and a generous donation of £100 from the Johannesburg City Council has been very helpful. This practical interest in the work of the Association is one which might be followed with advantage by some of the larger Municipalities of the Union.

Unfortunately, though there is a slight increase in membership, the receipts from subscriptions have decreased by £150, which means that many members have failed to meet their obligations with promptness.

It has been pointed out frequently that the financial position of the Association varies according to the venue of the annual meeting—a large town resulting in a large number of contributions and correspondingly increased printing costs while in a smaller town the contributions are fewer and the cost of printing therefore much lower.

It is held by some that the standard of the published contributions could be improved by a stricter editorial control and the money so saved used in other directions for the advancement of the aims and objects of the Association. Others again, are of the opinion that the JOURNAL offers an opportunity for those scientists for whom there is no society or association in the Union dealing specifically with their particular science, to obtain publication of original work and that any curtailment in this direction would result in a reduction in the status of the Association.

The Council has tentatively considered the matter, but to alter a policy which has been carried on since the inception of the Association is one which should not be adopted without full and adequate discussion by the members.

The funds available for printing are limited and the reserve built up in previous years, has almost been exhausted so that unless new sources of revenue are found, it will be impossible to publish in the future JOURNALS of similar size to many which have been issued during recent years.

It is for this reason that this report has touched on a matter which some may consider outside the scope of a treasurer's review.

JAS. GRAY.

Honorary General Treasurer.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

BALANCE SHEET AT 31st MAY, 1938.

LIABILITIES.

	£	s.	d.	£	s.	d.
Sundry Creditors—						
Open Accounts	£212	1	5			
Library Deposit	3	0	0			
Subscriptions paid in advance .	7	0	0			
				£222	1	5
Library Binding and Equipment—						
Balance at 31st May, 1937 ...	115	2	9			
Add—Interest on Library Endowment Fund	77	16	7			
	192	19	4			
Less—Expenditure during year	57	3	6			
				135	15	10
Revenue and Expenditure Account—						
Balance at 31st May, 1937 ...	62	16	0			
Add—Excess of Expenditure over Revenue for the year ended 31st May, 1938 ...	160	10	5			
				223	6	5
				581	3	8
Endowment Fund				3,070	3	5
Library Endowment Fund				2,164	11	6
South Africa Medal Fund				1,617	16	3
British Association Medal Fund				486	0	3
				£7,919	15	1

ASSETS.

	£	s.	d.	£	s.	d.
Cash—						
On Hand	7	15	6			
At Bank	243	16	1			
At Post Office Savings Bank, with interest accrued	151	10	6			
At St. Andrew's Buiding Society	75	2	10			
				£478	4	11
Sundry Debtors—						
Trustees — Endowment Fund— Balance of Interest not paid over	8	14	7			
Trustees — South Africa Medal Fund for expenses re 1938 award	8	17	10			
				17	12	5
Payments in Advance ...				10	0	0
Furniture—						
Balance at 31st May, 1937 ...	78	17	6			
Less—Depreciation	10	0	0			
				68	17	6
Medals on Hand				6	8	10
				581	3	8
Trustees' Endowment Fund— As per separate account				3,070	3	5
Library Endowment Fund— As per separate account				2,164	11	6
Trustees—South Africa Medal Fund— As per separate account				1,617	16	3
Trustees—British Association Medal Fund— As per separate account				486	0	3
				£7,919	15	1

We have examined the books and vouchers of the South African Association for the Advancement of Science for the year ended 31st May, 1938, and certify that in our opinion the above Balance Sheet correctly sets forth the position of the Association at the 31st May, 1938, according to the best of our information and the explanations given to us and as shown by the books.

Johannesburg, 13th May, 1938.

ALEX. AIKEN & CARTER, Auditors.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Dr. REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MAY, 1938. Cr.

Dr.	£ s. d.	£ s. d.	£ s. d.
To Salaries			£180 0 0
,, Rent			63 0 0
,, JOURNAL Expenses		£2,745 14 2	
Less—			
Government Grant	£250 0 0		
Johannesburg Municipal Grant ...	100 0 0		
Sales, Reprints, Advertisements and Discount ...	320 15 5		
JOURNAL Reserve transferred .	1,750 0 0		
		2,420 15 5	
			324 18 9
,, Printing and Stationery ...			7 18 9
,, Stamps and Telegrams ...			18 7 1
,, Insurance—Fidelity Bond and Workmen's Compensation ..			4 16 0
,, Expenses—			
Annual Meeting, 1937 (balance)		24 8 0	
Annual Meeting, 1938 (on account)		0 15 6	
			25 3 6
,, Sundry General Expenses ...			10 16 2
,, Grants to Local Centres under Rule 35—			
Witwatersrand		29 0 0	
Cape Peninsula		9 8 0	
Natal		6 18 0	
Orange Free State		3 11 6	
			50 17 6
,, Depreciation on Office Furniture			10 0 0
,, Balance, being Excess of Revenue over Expenditure for year ended 31st May, 1938 ..			160 10 5
			£856 8 2

Cr.	£ s. d.	£ s. d.
By Annual Subscriptions	£603 5 0	
,, Arrear Subscriptions	100 0 0	
,, Associates' Fees	8 0 0	
,, Students' Fees	2 2 0	
		£713 7 0
,, Interest—		
On Endowment Fund ...	126 19 1	
On Post Office Savings Bank Account	16 2 1	
		143 1 2
		£856 8 2

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

ENDOWMENT FUND.

Dr. REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1938. Cr.

To Interest as per contra, transferred to General Fund	£126 19 1	By Interest received during the year	£126 19 1
,, Balance transferred to Accumulated Funds	7 12 0	,, Sale of publications—British Association Account	0 2 0
		,, Life Members' Subscriptions	7 10 0
	£134 11 1		£134 11 1

BALANCE SHEET AT 31st MAY, 1938.

Liabilities.			Assets.		
Amount due to General Fund ...		£8 14 7	Investments in hands of Trustees—		
Accumulated Funds—			Capetown Municipality $3\frac{3}{4}$% Stock	£1,150 0 0	
Balance at 31st May, 1937 ...	£3.062 11 5		Capetown Municipality 4% Stock	300 0 0	
Add—Amount transferred from Revenue and Expenditure Account	7 12 0	3.070 3 5	Capetown Municipality 5% Stock	240 0 0	
			Capetown Municipality 5% Stock	800 0 0	
			Port Elizabeth Municipality $3\frac{1}{2}$% Stock	100 0 0	
			Cape of Good Hope Savings Bank	488 18 0	
		£3,078 18 0			£3,078 18 0

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

LIBRARY ENDOWMENT FUND.

Dr. REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1938. Cr.

To Balance transferred to Library Binding and Equipment Account	£77 16 7	By Interest received during the year .	£77 16 7
	£77 16 7		£77 16 7

BALANCE SHEET AT 31st MAY, 1938.

Liabilities.		Assets.	
Accumulated Funds—		Investments—	
Balance at 31st May, 1937	£2,164 11 6	£2,000 City of Johannesburg 3½% Local Registered Stock—at cost	£1,970 0 0
		Cash at St. Andrew's Building Society—Savings Bank Account	194 11 6
	£2,164 11 6		£2,164 11 6

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SOUTH AFRICA MEDAL FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1938.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Expenses in connection with 1938 Award ...	£8	17	10	By Interest received during the year	63	1	4
,, Amount of Award, 1938	54	3	6				
	£63	1	4		£63	1	4

BALANCE SHEET AT 31st MAY, 1938.

Liabilities.	£	s.	d.	Assets.	£	s.	d.	£	s.	d.
Sundry Creditors—				Investments in hands of Trustees—						
1938 Award and Expenses	£63	1	4	Fixed Deposit, South African Permanent Mutual Building and Investment Society, with interest accrued	£1,488	5	6			
Accumulated Funds—				Post Office Savings Bank ...	192	12	1			
Balance at 31st May, 1937	1,617	16	3					£1,680	17	7
	£1,680	17	7					£1,680	17	7

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE BRITISH ASSOCIATION MEDAL FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1938.

Dr.		Cr.	
To Awards	£30 0 0	By Interest received during the year .. .	£16 17 6
		,, Balance carried to Accumulated Funds	13 2 6
	£30 0 0		£30 0 0

BALANCE SHEET AT 31st MAY, 1938.

Liabilities.			Assets.	
Accumulated Funds—			Investments in hands of Trustees—	
Balance at 31st May, 1937	£499 2 9		£450 Union of South Africa 3¾ per cent. Local Registered Stock 1948/58 ..	£450 0 0
Less—Excess of Expenditure over Revenue ...	13 2 6		Amount due from General Fund ..	36 0 3
		£486 0 3		
		£186 0 3		£486 0 3

REPORT OF THE HONORARY LIBRARIAN FOR THE YEAR 1937-38.

The Association's Library is housed in Room 22, First Floor, in the Library of the University of the Witwatersrand, Johannesburg.

HOURS OF OPENING.

Weekdays. Term: 8.30 a.m. to 7 p.m.
Vacation: 9 a.m. to 5 p.m.

Saturdays. Term: 8.30 a.m to 12.30 p.m.
Vacation: 9 a.m. to 12.30 p.m.

EXCHANGE OF PUBLICATIONS.—During the year the following names were added to the exchange mailing list:—

1. Panstwowe muzeum zoologiczne, Warsaw, Poland.
2. Mathematical institute, Tbilissi, U.S.S.R.
3. Recueil mathématique, Moscow, U.S.S.R.
4. South-West Africa Scientific Society, Windhoek.

DONATIONS.—On the recommendation of Professor Paine at the meeting of the Association in Windhoek last year, as complete a set as available of the JOURNAL was presented to the South-West Africa Scientific Society. In return the Society presented to the Association's Library volumes 2-6 of their JOURNAL together with a copy of *The Diary of Hendrik Witbooi*. The Library is also indebted to the Royal Society of South Australia for their very generous gift of volumes 24-54, 1900-30, of their *Transactions* to replace the set which was destroyed in the fire of 1931. Gifts other than exchange material have also been received from the following—

1. British Museum (Natural History):
   Austen. E. E. Bombyliidae of Palestine.
   Cockerell, T. D. A. African bees.
   Guide to the fish gallery.
   Guide to the mineral gallery.
   John Murray Expedition. Reports. V. 3 No. 1; V. 4 Nos. 1-8.
2. R. A. Dyer. Botanist, Division of Plant Industry, Pretoria:
   Dyer, R. A. Vegetation of the divisions of Albany and Bathurst.
3. Geological Survey of Great Britain:
   Flett, Sir J. S. The first 100 years of the Geological Survey.
4. King and Jarrett, Ltd., London:
   South African Engineers' Register, 1937-38.
5. Dr. E. G. Malherbe:
   Malherbe, E. G. Educational Adaptations in a Changing Society.
6. The Chief, Division of Range Research, U.S. Forest Service:
   Range Plant Handbook.

PUBLICITY.—An application from *Current Titles from Engineering Journals*, N.Y., to receive current issues of the JOURNAL was agreed to, so that the contents of the JOURNAL is now indexed in this publication together with other scientific and engineering journals.

BINDING.—121 volumes were bound during the year under review. Binding and freight charges amount to £52 15s. 8d.

STOCK.—The Library now contains about 2,850 volumes. Periodicals currently received number 280.

ACCESSIONS TO SERIAL PUBLICATIONS, 1937-38

For a *Catalogue of Serial Publications in the Library*, and *Supplement*, see this JOURNAL, volume xxx, pp. xxv-xxix and volume xxxiv, pp. xxxiv-xxxvii.

Illinois. University.
Illinois Biological Monographs. 14, 1935+.

Mexico. Universidad Nacional. Instituto de Geologia.
Anuario. 1932+.
Anales. 6, 1936+.

National Physical Laboratory, Teddington.
Abstract of Papers. 1936+.

Porto Rico. University. Agricultural Experiment Station.
Annual Report. 1935/36+.
Bulletin. 44, 1937+.
Circular. 104, 1936+.

Recueil Mathématique. Moscow. 1, 1936+.

Royal Society of South Australia, Adelaide.
Transactions and Proceedings. 24, 1900+.

South-West Africa Scientific Society, Windhoek.
Journal. 2, 1926+.

Tbilissi. Institut Mathématique.
Travaux. 1937+.

Abbreviations and symbols used:—

+ indicates that the serial is currently received and that the set is complete from the last volume or number given.

P. FREER,
Honorary Librarian.

P.O. Box 1176, Johannesburg,
9th June, 1938.

OBITUARY.

Professor HAROLD BENJAMIN FANTHAM, M.A. (Cantab.), D.Sc. (London), 1876-1937.

In Dr. H. B. Fantham the Association has lost a distinguished member who not only carried out important researches in his own chosen field of Zoology and Parasitology, but also served the Association consistently as either an officer or a delegate.

For a number of years he was Honorary Editor of Publications, and during that period largely was responsible for the raising of the standard of the *South African Journal of Science*, and for bringing about a much wider circulation for it. In 1927 Prof. Fantham was President of the Association, at the Salisbury Meeting, while in 1931 he was the recipient of the South African Medal and Grant for his scientific contributions.

A graduate of Cambridge and London, Fantham had a distinguished University career; at London he was awarded the gold medal for Zoology, and was Derby Research Scholar, while at Cambridge he was Darwinian Prizeman and University Assistant to the Quick Professor of Biology.

After holding posts in the St. Mary's Hospital Medical School at University College, London, and in the Liverpool School of Tropical Medicine, Dr. Fantham was appointed in 1917 to the newly created Chair of Zoology and Comparative Anatomy in the institution now known as the University of the Witwatersrand, Johannesburg. Under his direction the new Department soon became known as a centre for Zoological research, particularly in Protozoology and Parasitology.

Dr. Fantham was a clear and capable lecturer, who had the ability of developing and holding the interest of all classes of students.

With a wide range of interests, and notably in human heredity and eugenics, he did much to further the work of several societies concerned with important social problems, and frequently attracted large audiences to lectures he was invited to deliver upon such matters.

In 1933 he accepted an invitation to occupy the Strathcona Chair of Zoology at McGill University, Montreal. In his new sphere Professor Fantham soon was responsible for bringing about further development in the activities of his Department, particularly in connection with research in freshwater biology. Under his direction the Department rapidly increased in student numbers, while research students were attracted to undertake work under his stimulating guidance.

On the 26th October, 1937, Science suffered a great loss in the passing of a capable and stimulating personality and exceedingly compelling and enthusiastic exponent.

No tribute to the memory and to the scientific, administrative, and teaching work of Harold Benjamin Fantham, however, could be in any way complete without a reference to the splendid aid and co-operation he for many years received from his wife, so well known as Dr. Annie Porter, herself a distinguished Zoologist. To Mrs. Fantham the Association and the African world of Science that it represents, extend sincere sympathy in her heavy loss.

J. P.

PROFESSOR ANDREW YOUNG, M.A., D.Sc. (Edin.), 1873-1937.

South African Geology has lost in Prof. Andrew Young a distinguished student, a highly successful teacher, and a widely known and beloved personality.

After studying at the University of Edinburgh under those famous geologists, the late Professor James Geikie and Sir John Flett, Young for a time studied educational methods at the Edinburgh Normal Training College. Later he was engaged in the organisation of science teaching in Gloucestershire. After lecturing for a time on Geology at the Heriot-Watt College, Edinburgh, he was appointed to the Professorship of Geology at the South African College, now the University of Cape Town—following the notable geologist the late Dr. G. S. Corstorphine.

Professor Young become known for his general range of geological interest and knowledge, and was responsible for giving guidance and help to many scientific workers, students and others requiring information or stimulation. With his kindly and attractive personality and his teaching gifts, Professor Young succeeded in arousing real enthusiasm among his students, several of whom to-day are themselves notable geologists.

Prof. Young died on 7th November, 1937. To his brother, Professor-Emeritus R. B. Young, also a geologist of high distinction, the Association extends its deep sympahty.

J. P.

DR. ALEXANDER WILLIAM ROBERTS, Hon. D.Sc., F.R.A.S., F.R.S.E., 1857-1938.

In the death of Dr. A. W. Roberts, so notable a figure in Native Education, Native Policy, and Astronomy, the Association has lost a most distinguished and very highly honoured member.

Dr. Roberts achieved distinction in several fields—in the splendid work he did for Native Education, Native Policy, and in the sphere of Astronomy.

Arriving in South Africa at the age of twenty-five, Roberts for many years threw himself whole-heartedly in

Native educational work; at a later stage he served on various Commissions appointed to consider Native matters of various kinds; ultimately he became a Senator to represent Native interests, and Chairman of the Native Affairs Commission. His name has an honoured place on the roll of those who have attempted to educate and otherwise aid the Native of South Africa—the Natives at all events will never forget him who toiled so single-heartedly to serve them.

Roberts also will long be remembered for his work upon variable stars, a study which commenced as far back as 1888, and had to thank for its initial encouragement Gould, Pickering and Gill. In 1890 a small observatory was ready to his hand, at Lovedale, near Alice, where his principal work for the Natives was centred.

Beginning with very inadequate apparatus, which later was added to and improved, Roberts was able to collect information for many contributions to the papers of the Royal Astronomical Society, the Philosophical Society of South Africa (forerunner of the Royal Society of South Africa), and other learned bodies.

His interest and keeness largely are responsible for the existence of an active band of amateur observers in the country.

In 1908, Roberts was President of Section A, in 1912 received the South Africa Medal and Grant in recognition of his astronomical researches, and in 1913 was President of the Association.

He was an honorary graduate of the University of Cape Town.

A man of considerable ability, strong force of character and transcendent integrity, A. W. Roberts was a splendid son to his adopted country.

He died on 27th January, 1938, widely mourned, and nowhere more than in Native circles.

J. P.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 1-18, December, 1938.*

THE SCIENCE OF LANGUAGE.

BY

PROFESSOR L. F. MAINGARD,

University of the Witwatersrand, Johannesburg.

PRESIDENT.

Presidential Address delivered 4 July, 1938.

This year the subject of your President's Address is the "Science of Language." The choice of the subject follows from the fact that the Association has elected to have a professional linguist as its President for the first time in its history, and before I proceed further, it is, I think, my duty to pay a tribute to the wide and liberal point of view taken by the members of the Association in conferring this honour on me personally and, more particularly, on the Science I represent. And I shall try to repay the gratitude I feel in my present position by passing in review with you some of the salient facts of "language," to discuss its true nature, and the advances which have been made in recent years by the growing band of international workers in this field of knowledge, of which the man in the street has heard little or nothing.

A consideration of these recent advances will no doubt interest you. It will show you that linguistic science, in the first period of its development, by adhering to strictly scientific methods, devoted itself exclusively to the understanding of the earlier phases of language and to the study of their evolution. It has of more recent years been co-operating with sociology, psychology and mental pathology in solving its own problems and arriving at a better understanding of that most elusive branch of the human sciences—the language of man. It is asking itself under what conditions it evolves, how it functions, not only as regards the individual, but as an indispensable condition of social life, and how it disintegrates under the influence of lesions of the human brain.

It will further show you—a not unimportant part of the picture I shall attempt to present you to-night—how the science of linguistics has benefited by this "holistic" or, as some botanist might perhaps say, this "ecological" procedure. It will teach us that great lesson we are so apt to forget, that in the human sciences more especially, the varied and tangled skein of human motives and reactions cannot be unravelled by the study of one set of facts or the use of one set of scientific methods alone.

Grammar and Logic.

By "Science of Language" I do not mean "grammar" in the sense in which most of us understand it from the recollections of our school days; a branch of the school syllabus to which plenty of us took a dislike, perhaps because its value or usefulness was not apparent on the face of it In any case, it is not my intention to revive unpleasant memories by reminding you of "subject" and "object," of "declensions of nouns" or of that soul-deadening and uninspiring exercise called "parsing." This generally represents the sum-total of the linguistic training which most men get, and we naturally base our idea of language upon it. It is therefore necessary to show how such a conception of language has retarded its true scientific study for quite a number of centuries, for it is as old as the dawn of civilisation.

"Grammar" is a heritage from the Greek sophists. They invented it, and to them and, more especially to the great Greek philosopher Aristotle, we owe the notions of "parts of speech" and "declensions" and the names still actually in use in our schools. They made a careful analysis of their language, such as it was spoken and written, but did not condescend to record any of the languages which flourished around them, which they looked down upon with contempt, as those of the barbarians, of the *βαρβαροι*. This contempt reveals the true nature and the aim of their efforts, which was to describe and to set down a standard in the practical use of the language It was their object to lay down a body of rules which their disciples had strictly to observe in order to speak and write correctly. This is still the spirit which inspires all our modern grammars.

Look at English. There is a so-called "standard English," which we are supposed to be educated up to and the norm for which is the English spoken at the public schools and generally by the educated classes in England. Imbued by the method described above and which we have learnt at school, we are constantly asking ourselves whether this pronunciation is right or that construction is wrong, whether, for example, we should say "*rémonstrate*" or "*remónstrate*," or whether we are wrong in saying "it is me" instead of "it is I." In acting thus we are treating language as if it were fixed and stable for ever, and not allowing for that great principle of development or evolution which is now recognised as a feature of language and the recognition of which, as we shall presently see, was so essential for the rise of a genuinely scientific study of language. Nor must we forget the influence of the two great languages of antiquity, Latin and Greek, during the Middle Ages, and the Renaissance, in confirming that point of view. They were then "dead languages;" that is, they were definitely fixed, a norm could be laid down and Cicero and Vergil held up as models for refined and correct Latin. Being dead languages, only their written form was known and studied, and this subservience to the written word distracted attention from the conditions under which normal, living speech functions.

There is still another point involved in that narrow conception of language. It is the close association of Logic—Formal Logic—and language. The closeness of this association is demonstrated by the fact that the Greeks used the same word λόγος to denote both " word," " language " and " reason," i.e. logic, and further, by the fact that many words are common to both the terminology of grammar and of logic, such as " subject," " predicate," " attribute," etc. In actual fact, there is not always this close identity. There is in language not only this logical element, there is also the affective or emotional side. The language we use is not merely an instrument for the expression of our intellectual life, of our abstract conceptions. Thus, when we open our paper in the morning, we may read: " There was another railway accident yesterday. There were thirty victims, of whom three were killed." These sentences are purely logically worded. Then, reading further on, we notice the name of a man we knew well. Immediately we exclaim: " What! So-and-so dead? Too tragic! " Here we can realise the difference between the logical and the emotional uses of language. Again, note the colourless, passionless voice with which the school-boy recites a sentence such as this: " Harold was killed at the battle of Hastings in 1066." The event has happened so long ago that it has taken the form of a mere abstract conception in his mind. But he speaks more feelingly when he has just returned from a visit to his headmaster as a result of some escapade for which he has had to pay the penalty. I have given you some extreme examples to mark more sharply the distinction between these two elements in language—the emotional and the logical. But it may be added that even when we use a logically constructed sentence, we are inspired in doing so by some subjective impulse. We must remember that language is not only an instrument for thinking, but its object is also to influence the conduct of our neighbours. We speak, because we have something to say or at least because we think we have something to say.

Further than this, the logic we have constructed fits in with our European languages, but this is not necessarily the case when we examine other linguistic systems, such as Chinese or Bushman. These people may, and often do, come to the same conclusions as we do, but their logical technique is very different from ours. This is largely the result of difference in grammatical structure. In Chinese, as you know, words are invariable. There is no distinction between a noun, a verb or an adjective: they are interchangeable. There is no plural or singular. To understand the full implication of these features of Chinese as compared with our own speech, a few illustrations are indispensable. They will be taken from Karlgren's *Sound and Symbol in Chinese*:

(i) *T'ai K'ang shi wei;*

(ii) *fei ts'i ch'u ye;*

The word-for-word translation of the first sentence is: " T'ai K'ang (a Chinese Emperor) corpse throne-place," and one would

be tempted to interpret these words thus: "T'ai K'ang's grave (= corpse-place)." But the true meaning is: "T'ai K'ang was in the state of a corpse relative to his throne," or, in better English, he behaved like a corpse on his throne, i.e. he did not take any interest in the State.

The second sentence means, word for word: "no seven go-out." Even when these cryptic words are restored to their context (they refer to the seven grounds for divorce in Chinese customary law), we are no wiser. They actually mean: "(This is) not (one of the) seven (grounds for) repudiation."

It will be clear, on comparing the literal and the correct versions, that the former contains none of the morphological or other linguistic devices that indicate the relations of the words to each other, and this causes the obscurity of the literal version. But the sense becomes immediately obvious when we add these devices as we are bound to do in the correct English version. That is, Chinese, structurally, comes very near the state of language which exists in the mental condition known as the syntactical aphasia of Head, where the patient is unable to use those formal elements of language, resorting to what has been called the "telegraphic style," and this has been precisely recognised as a disorder affecting memory and logic. Of course, there is here no suggestion that all the Chinese suffer from syntactical aphasia, as this is a pathological condition occasioned by a lesion of the brain which causes a loss of what the patient possessed before, which is not the case of a healthy brain. It is merely contended that, compared with our logical system, there is a gap in the Chinese logical system caused by a lack of the formal elements of language and consequently their reasoning technique is not the same as ours, as it is not so closely knit.

Chinese is not the only language of this type, Bushman has close affinities with it. This statement must not be misinterpreted to mean that Chinese and the Bushman dialects are related linguistically in any other way than structurally or that they are related linguistically as belonging to the same "family of languages," as this term will be defined subsequently. It is intended merely to convey that they possess the same lack of formal elements, the same tendency to juxtapose, i.e. to piece together words without relating one to the other with formal grammatical words, instead of the process of subordination normal to European languages. I may be allowed to choose only two sentences from the *ǂkhomani* dialect, among the many I have collected, as specimens. *xen ǁŋa ǁ'uĩ /'ci*, "literally": (I) "be there sun go down," and in better English: "I was there until the sun went down." Or *cesi /ŋau suĩ ŋ/ka*, "literally": "I come marry sit be with you," or better: "I shall marry you permanently." In both cases we see the same process of piecing together of the elements of the sentences and consequently the same logical processes as in Chinese.

Enough has been said to prove that the old "grammar," in the first place, overlooked the important part played by emotion in the functioning of man's speech. In the second place, it wrongly assumed the universal character of the logic which had been devised by its contemporaries, through its ignorance of languages other than European ones. Through this narrowness of outlook and its neglect of the observation of facts, and through its stressing the empirical side of language, it was never in a position to establish linguistic studies on a scientific basis.

Comparative Grammar and the Rise of the Evolutionary Theory.

The contacts of the Europeans with India led to the "discovery" of Sanskrit, which gave the necessary stimulus to a new point of view in the study of languages. The French Jesuit, Coerdoux (1767) and Sir William Jones (1786) drew attention to its affinities with the two ancient classical languages of Europe. "No philologer," said Jones, "could examine them all three without believing them to have sprung from some common source. . . . There is a similar reason to believe that both the Gothic and the Celtic . . . . had the same origin with Sanskrit; and old Persian might be added to the same family."

But there was more in Sanskrit than the brief indications which these two scholars had given. Sanskrit—which is in its earliest form Vedic—dates back probably to over 3,000 years ago. It had been preserved for centuries as the religious language of India, and, on account of its sacred character, every effort had been made by the native Indian scholars to keep its old writings and their pronunciation in the original form in which they had been handed down to the Brahmins. To achieve this purpose, the Indian grammarians took a very great deal of trouble in ensuring the accurate description of its sound-system and its grammatical structure. This minute analytical work clearly showed to European linguists, who subsequently became acquainted with it, the points of interest of Sanskrit as compared with Latin and Greek. It appeared as an extremely archaic idiom in its morphology, more especially in the declension of its nouns and the conjugation of its verbs and its sound-system.

With a knowledge of Latin and Greek alone, it had never occurred to anyone in Europe to trace in detail the similarities of these two languages. Sanskrit grammar was a revelation, all dissected and made available as it was by the Indians. It provided the missing link. The western philologists had known, for instance, the two pairs: *genus* (nominative)—*generis* (genitive) and γένος (nominative) and γένεος (genitive), both meaning "genus" or "kind," in Latin and Greek respectively, and yet they were never able to explain the second term of these two pairs (i.e. the genitive form). But with the Sanskrit pair *janas*, *janasas*, the problem of their relationship is clarified, as we learn

by comparison that the original form contained an *s*, which had disappeared in Greek (γένεος), and had become *r* in Latin (*generis*).

Let us now see what we can infer from a comparison of the forms in these different languages. Take the word for "brother," which is in Sanskrit *brathar*, in Greek φράτωρ, in Latin *frater* and in Gothic *brothar*. From this series of words and limiting ourselves to the initial sound, we can deduce the following linguistic equation:

Skt. *bh* = Gk. φ = Lt. *f* = Gthc. *b*.

and we can conclude that the original sound in the parent language was *bh*.

Similarly, another series, for the words denoting "I bear," in Sanskrit *bharami*, in Greek φέρω, in Latin *fero*, Gothic *baira*, giving the same linguistic equation and enabling us to restore hypothetically, the original form as * *bhero*. If we go on examining the words of these different languages beginning with the same sound, we have the same result. The terms of the equation are constant. They remain unchanged.

If we try another initial sound, e.g. the initial *p*, as in the word for "father," we have in Sanskrit *pitar*, in Greek πατήρ, in Latin *pater* and in Gothic *fadar*, with the equation Skt. *p* = Gk. π = Lt. *p* = Gthc. *f*. An examination of all the other words beginning with the same sound confirms the equation. In other words, all these concordances between the different languages are regular.

It is the task of the comparatist to accumulate these concordances, not merely for the sounds, but also for the grammatical forms or, as they are technically called, the morphology, and when these concordances are in sufficiently large numbers and repeat themselves regularly, he can conclude that these languages have a common origin and that they are, therefore, related. These languages we have just discussed thus belong to the same *family*, which is usually called Indo-European, or, as the Germans prefer to say, Indo-Germanic, and extend from the west of Europe right into India. These concordances are the only realities with which the comparatist can operate. In fact, Indo-European has been defined as "a well-defined system of correspondences which exist between languages which have been recorded in historic times." This present-day conception was far from being that of the founders of the science of comparative grammar—F. Bopp, Pott and Schleicher.

Bopp had come to Paris in the early years of the XIXth century to learn Sanskrit, and in 1816, on his return to Germany, he published his *Conjugation-system of the Sanskrit verb*. In this work Bopp brought together the grammatical forms of Sanskrit, Latin, Greek, Persian and Germanic, and proved the essential unity of the languages. Important as this result was, it was not the end he had in view. His dream was to use the

correspondences he had proved to arrive at what he believed to be a more " primitive " state of the grammatical forms he had been dealing with. This is, however, an assumption which far exceeds the modest claims of the modern conception which we have just described and which has been rejected by it. He and Pott succeeded, however, in laying the foundations of comparative grammar, although they had misunderstood the limitations of its methods.

Schleicher went a step further. He had many scientific interests. Botany had claimed his attention and he realised the importance of scientific observation. He was a staunch supporter of the Darwinian theory. His most interesting work is summed up in his *Compendium* in which, going beyond the mere comparison of his two predecessors, he reconstructs by inference what he lays down as the actual words of prehistoric Indo-European. His belief in this reconstruction was so great that he also published the connected text of a story in this so-called " indogermanische Ursprache." The undertaking seems, to say the least, a rash one in the eyes of the modern linguist. For all these reconstructed forms are merely hypothetical, as prehistoric man in Europe or in India was not in a position to leave any texts of his language since he did not possess the art of writing. Yet, Schleicher, while expecting too much from the methods he had renovated, made a great contribution. He had introduced the conception of the evolution of language. In his *Compendium* he quotes first the restored Indo-European word, then the corresponding ones in the other languages, thus stressing this essential fact, that languages change in the course of their existence.

This very important principle was further emphasised when the comparative grammar of the more modern phases of the Indo-European languages reached a sufficiently advanced stage. This was more especially the case with the Romance languages, the present-day representatives of Latin, i.e. French, Italian, Spanish, Portuguese and Roumanian. The comparatists who worked in this field were in a singularly fortunate position. The parent language, Latin, was fully known and there was no need for hypothetical reconstructions. Further, the weakness of such reconstructions as in the case of Indo-European soon became apparent. In the second place, there was an abundance of records of the different stages through which the languages of the group had passed in the natural process of their evolution. These were minutely followed up. The concrete nature of the facts collected eliminated the old arbitrariness and subjectiveness. It was finally realised that Sanskrit or prehistoric Indo-European, as reconstituted, did not represent a " primitive " state of language, because it is a stage, just as Latin or French are stages, in the development of the parent language.

What are the net gains we can now register? The chief one is the application of evolution to language and the regularity of the sound or phonetic changes on which it is based. Subsequent

research in comparative grammar has only perfected the methods and added new facts and discoveries. But the scheme of the research has remained essentially the same. If we unite all these findings of linguistics, we can now present a broad picture of the evolution of Indo-European. It is the prehistoric language of an extremely enterprising ethnic group which lived, according to some of the latest theories, in the Khirgiz steppes in western Asia, as wandering pastoralists who later turned to agriculture. Under economic or climatic pressure there were successive waves of migration from the parent stock. Small groups "hived off" and launched themselves towards the west, into Europe, and towards the south-east into Persia and India, to conquer new lands, for they were essentially a warrior nation. There were, however, indigenous populations in the territories they conquered and on them they imposed their language and their social organisation, some of the elements of which were well defined, such as their family organisation and their chieftainship. These facts have been proved beyond doubt by the recent researches of linguistic science.

The fragmentary character of these invasions partially explains the formation of independent linguistic groups, which evolved differently from each other, when the speakers became separated. Another factor must be taken into account. It is what has been called the "substratum," that is the influence exercised on the language of the conquerors, which they adopted, by that of the conquered. For to the latter Indo-European was a foreign language and we know by our own experience that we are apt to introduce our own linguistic habits into the foreign tongue we acquire. So the parent language developed into Celtic in the west, Italic and Germanic and Greek in Central Europe, the Slav group in the east, Armenian, Persian and Sanskrit in Asia. These again, in course of time, split up into sub-groups within each group, for the same causes of disruption and change repeated themselves, and in this way the Celtic group is continued in the modern forms of Welsh, Breton, Irish and Gaelic; the Italic group, that is through its chief representative, by the Romance Languages; Germanic by English, Dutch, German, the Scandinavian languages and so on. And we say that these belong to the same "family of languages," namely the Indo-European.

I have spoken in detail of Indo-European, because, in its early years, comparative grammar confined its attention to that family and, therefore, it is the best known and, having been most fully studied, provides us with the greatest amount of results. But there are other families of languages, such as the Semitic-Hamitic, comprising Arabic, Hebrew, Amharic, most probably Ancient Egyptian, to name only the best-known; or, in our continent of Africa, the Bantu family, which stretches southwards from the Congo and which includes Zulu, Xhosa, the Chwana groups, etc. It stands to the credit of the great linguist Meinhof that he proved the existence of this family.

There are many more families of languages. Some languages have not yet been incorporated into a family, like Chinese. The reason is that linguists largely rely on the morphology, which comprises the noun-forms, the verb forms, pronouns, etc., and which is therefore the most stable part of language. Chinese, as we have already seen, is extremely sketchy in this respect and does not lend itself to this type of classification. It is the aim of linguists to discover new families. I have myself attempted to prove the kinship of all the " click " languages of Africa, more especially Hottentot and Bushman (1934). It is Meinhof's theory that Hottentot originally had no clicks, which it borrowed from Bushman. But it was shown by me that there are certain morphological features (e.g. the use of pronouns to denote the plural number), which are common to both groups. This has not yet been refuted. On the contrary, quite recently Professor Beach, late of Cape Town University, has conclusively demonstrated that the clicks are an original element in the Hottentot dialects, and, I conclude, could not therefore have been borrowed by them from the Bushman, as has been alleged. So that there is every reason to believe that we have in South Africa a newly recognised family of languages.

Phonetics and Phonology.

The part played by sound changes in the evolution of language had stressed the importance of a study of sounds in themselves and for themselves, which it now became the object of the new science of phonetics to analyse and classify. The recognition of the existence of separate sounds as components of the word is no new thing. The Sumerians, more than 5,000 years ago, had already split up the word into syllables in their cuneiform writing and the Greek alphabet, of which our modern script systems are directly descended, embodies the idea in that it attempts and did at first actually represent one sound by one letter.

In the middle of the XIXth century, the investigations of physiologists and physicists, like Brücke, Czermak and Helmholtz, had led to brilliant results, and in explaining one of the most important functions of the human vocal system, e.g. the rôle of the vocal cords, of the soft palate and of the tongue in increasing or decreasing the capacities for resonance of the mouth cavity. But, vital as they were, these discoveries were of a sporadic nature. The systematic study of phonetics is of a slightly later date, and in 1876, Sievers published his " Outlines of Phonetics."

Sounds have been classified; their mode of formation and the speech organs extensively inquired into; tone, rhythm and stress have been studied. During the last 60 years, in England, Germany, France and the United States, investigations have been steadily carried on and we can say that to-day the linguist and the phonetician have at their disposal very complete and very accurate descriptions of the sound systems, not only of the great

cultural languages, like English and French, but also those of the less extensively used languages and dialects of the world.

At first, the phonetician had to rely on his ear and though it was specially trained, there was always the possibility of an element of subjectivity affecting the observations of the man gifted with the best and most highly developed sense of hearing. The need for a more objective method of approach has been secured by the introduction of mechanical devices and accurate apparatus into our phonetic laboratories. Thus, the kymograph enables us to detect the most delicate features of sound which would be lost to the " naked " ear. The air vibrations caused by the subject who speaks into a mouthpiece are registered by the stylo or needle on to the carbon surface of the drum of the kymograph in the shape of lines. These are subsequently transferred to sheets of paper, which can be examined at leisure, so that any question as to the details of a particular sound formation can easily be checked or clarified by these kymograph tracings. Again, in the Phonetics Laboratory of the University at Johannesburg, there has been established a very large and up-to-date electrical recording plant. The speech sounds are carried from the microphone to the plate which registers them and the records can be reproduced on others and used for the purpose of analysis. We have already taken a large number of records containing Bushman and Hottentot speech specimens and folk-tales. It is hoped that further specimens in other languages and dialects within the Union will be secured and a " Speech Archives " thus formed in order to preserve the most fugitive types of speech, such as the fast disappearing Hottentot and Bushman dialects. Apart from the important aspect of preservation, the advantages of speech records of this sort are obvious over the human subject, as they can be made to revolve fast or slowly and can be stopped altogether, the particular word being repeated as often as required for analysis. I have chosen these examples, among a number of others in use in our laboratories, as two of the most important and instructive ones.

Interesting practical applications have been made of the results obtained; for instance, in the teaching of foreign languages and in the correction of speech defects. The learner of a language not his own often finds difficulty in pronouncing certain sounds, such as, in the case of an English speaker, a Zulu click, or the difficult Hottentot sound-complex *kx'*, or again the French *u* or the German *ü*, which have the same value. He fails because he does not know how they are formed or because he has not obtained sufficient control over the organs which come into play in their formation. With an accurate phonetic knowledge he can be directed to place his speech organs in the right position and, by practice on this advice, the difficulty will probably be overcome. In the case of speech defects, the most common and widespread form of which is stammering, there is attached to the Phonetics Laboratory of the Johannesburg University, a

" speech clinic " for the cure of such defects. Dr. Pienaar, our phonetician, who is in charge of the clinic, has ascertained that 5 per cent. of our school children on the Reef have speech defects and 2 per cent. are stammerers, and the subjects sent to him are tested and then put through a course of scientific speech training. The results obtained are extremely encouraging in a large number of cases. This is at present the only centre of its kind in the Union. It is to be hoped that the idea may spread and receive as wide an application as in Germany or the United States of America, with their numerous " speech clinics " and training centres for teachers for speech defectives.

The science of phonetics takes sounds in an isolated way, analyses and dissects them, so to speak, and we have seen the undoubted advantages which result. But linguistically an isolated sound has no existence. An *r* or an *a* or a *t* each pronounced by itself may be an interesting phenomenon but it is meaningless, so far as language is concerned. It only acquires linguistic significance when it appears in a sound-complex which is a word. For, when, instead of pronouncing these three sounds separately, we link them together and say *rat*, we have a definite picture before us. That is, sounds have their full value, when they are combined and opposed to each other. It is then that they become related to living speech. These facts have recently stimulated some linguists to study these sound oppositions and combinations in the different languages. Troubetskoy and the Prague school have devoted a great deal of attention to these problems. It is a very interesting line of investigation, to which the name of Phonology has been applied. But it is too early yet to know what discoveries or new orientations we may finally expect from it.

Language and Sociology, Psychology and Mental Pathology.

Phonetics is benefiting by its contact with physics, the anatomy and the physiology of the speech organs and generally from the adoption of scientific methods. There have been many such contacts between linguistics and kindred sciences in recent years. But we shall here limit ourselves to three instances in which definite results can be mentioned, namely, sociology, pyschology and mental pathology.

Language is a social institution, just as much as law, religion or art. In fact it is the most necessary of all social institutions, for it is difficult to conceive of community life without it. The traditions and accumulated experience of centuries are transmitted from the ancestors to the descendants in the process of the acquisition of language.

A stranger who comes into a community whose language he does not understand is an outcast. The deaf and dumb live in a world of their own, without contact with the outside world, unt

they acquire the means of joining, to some extent, in the life of the community, by lip-reading and the teaching of sound production. Within the community itself there are social classes, with linguistic mannerisms of their own, technical vocabularies and slang. If you speak Cockney English and only Cockney English, you will be refused admission to a social clique whose members speak only Oxford English. Again, language is an outward bond of union among members of a particular social class. Thus the technical vocabulary belonging to the turf binds together all those who are interested in it and separates them from the rest of the community.

Let us examine more closely the implications of the social character of language.

One of its characteristics is that of being outside the control of the speaker and at the same time compulsory upon him. When he learns his mother-tongue in childhood, he acquires it as a system transmitted to him as a whole. The child receives it as given to him without any power to alter it. All his mistakes are carefully corrected until his language, at first amorphous, becomes substantially the same as that of his entourage. Once the mother-tongue has been acquired, the individual is not afterwards at liberty to introduce changes or make innovations contrary to the system. A child who would insist on using exclusively words of his own invention—such cases are on record, although few in number—or a man struck with aphasia—that is, who deviates considerably from the accepted norm—is outside the pale of his linguistic group and pays the penalty of his strangeness by not being understood. Sometimes the penalty is even more dramatic, as in the case of the English missionary in China who, intending to speak of "God," should have said *chu* (with rising tone), but, in the excitement of the moment, substituted *chu* (with level tone), "pig." I need not describe the result.

Another characteristic of language is the arbitrary nature of the meaning in relation to the word or, viewed from the opposite side, of the word as regards the meaning. There is no necessary and inevitable relationship between the two. The same concept is expressed in different languages by different words. Thus, the English say: "horse," the French, "cheval," and the Afrikaners, "perd." There is no reason why the English should not have used "cheval" or "perd" instead of "horse." Hence language can be described as a system of signs or symbols which are purely conventional.

There is, however, this paradoxical situation. Language has all the features of a social institution. It is a system imposed from outside upon the individual who has no power to change it. Yet it is the individual who is constantly using this system and this individual act—to adopt the classical term—we shall call "speech," and "speaker" the individual who uses it. Now, language as we have seen, is subject to changes, to the forces of evolution. How can these changes take place? How is it

possible, under the circumstances, that our twentieth century English is so different from Elizabethan English or modern Italian so different from Latin, that Shakespeare would be unable to understand a play of Bernard Shaw or Cæsar a speech of Mussolini? The explanation is a complex one. The individual speaker cannot *voluntarily*, as an act of individual will, impose changes of his own making on language. It is the accepted norm to say: "His speech was broadcast." We may hear an individual speaker say: "broadcasted," but his analogical creation is not universally accepted and it dies a natural death. Secondly, these linguistic changes are *unconscious*. The speaker has not the slightest impression that language is changing the whole time. To him language is *static* and not *dynamic*. What increases the impression of the *static* aspect of language is the fact that those changes are very slow; they are spread over a large number of years. Thus the change from Old English *ba:t* to the modern English *boat* was very gradual and insensible to generations of speakers who changed it. Thirdly, the "laws of phonetic change" are constant and rigid, but only for a given period of time and for a given language at that time. To that extent and as far as the linguistic group is concerned, they are of universal application and must correspond to its general tendencies. It is wrong, therefore, to think of language in terms of an "organism," in the biological sense, or of the "life of language," as it only exists in the minds of the speakers and as it is the accidents occurring in "speech" and in its transmission from one generation to another, that condition these changes.

Since language is a social institution, it reflects the historical and social events which have affected the community which speaks it. We can trace these internally, in the vocabulary, for instance, or externally, in the force of expansion which a given language receives from political circumstances. Thus, in 1066, William the Norman defeated Harold at the battle of Hastings. One of the consequences of this conquest of England was the establishment of a foreign aristocracy with Norman-French as its language. Now, if we look, for example, at the terms denoting titles of nobility in modern English, we find *duke*, *marquis*, *count*, *baron*—all words of Norman-French origin. We still address the King or a duke with an old Norman-French word, readapted to the English pronunciation, namely, "Sire" in the first case, and "Your Grace" in the other. The history of the Roman Empire will illustrate the second type of the influence of historical events on language. When the Romans had become the lords of an extensive empire, their political expansion brought with it the geographical expansion of Latin. The unity of Roman civilisation created a unity of language over the whole extent of the Roman Empire. When the Germanic invasions in the middle of the fifth century gradually broke up the Roman Empire, Latin forfeited that unity it had enjoyed and was broken up, after some violent convulsions, into the modern Romance languages. Such is the

force of that aspect of the social life of a nation called political power on the expansion or retrogression suffered by language.

We have just dealt with "speech" and the individual speaker. What is the mechanism which exists in him for the production of speech? What comes into play which enables him to see an object called "door" and to say the word "door?" The anatomical and physiological aspects of the question are plain enough in their main outline. The parts of this anatomical mechanism are: (i) the retina of the eye; (ii) the thalamus—in the mid-brain (which has to do with visual senations) and (iii) the cortex of the brain. The different parts of this anatomical mechanism as enumerated are connected by different nerves or fibres, in the case of the thalmus and the cortex. It is a system of lines through which the physiological reactions taking place in the different parts are transmitted.

The picture of the object "door" is focussed on the retina and then carried to thalamo-cortical regions. This message is now associated with the result of another series of reactions, i.e. auditory reactions, which had previously taken place along a separate anatomical mechanism, when the air vibrations composing the word "door" first struck (i) the ear-drum or "tympanum" and were passed on, by a similar system of nerve and fibre-tracks, to (ii) the "cochlear nuclei" and the "medial geniculate body" of the thalamus and (iii) to the cortex, and was stored somewhere in the brain, for the purpose of association, which has now arisen. This association of visual and auditory impressions now stimulates the "motor centres," which in their turn set in motion the muscles controlling the organs of speech and a series of air-vibrations issue from the mouth, which form the sound-pattern of the word "door." This description of the more material side of the linguistic processes, even if it were more detailed or more adequate than I feel competent to give, leaves a good deal to be explained.

We must now turn to the recent experiments and theories of psychologists for further explanation. In this field of research the observations of Köhler, Yerkes and Miss Learned on the anthropoids are extremely illuminating. The forms taken by these experiments are calculated to test the mental power of the animals. A banana is hung out of the reach of a chimpanzee and a stick is in the neighbourhood. The animal knocks down the banana with the stick, after repeated trials to get at the banana before he thought of using the stick or similarly, there is a box which, after repeated trials and failures, he succeeds in using for the same purpose. Another experiment consists in covering two cages, one with red and the other with green material. Food is placed in the red cage consistently. The animal goes to the red cage after a few days' experience. Even if the cages are displaced, he goes to the red one, as evidently he has associated the red with food. What deductions can be made from these and other series of similar tests? We can say that the animal has learnt the use of tools and that he recognises colour. but he does

not necessarily use the tool as intelligently as a human being, for, when the tool and the banana are in different fields of vision, i.e. if the stick or the box happen to be behind him, he does not use them. Again, his notion of colour is a purely concrete one. It is a symbol which adheres strictly to the concrete. The sum total of these experiments is that Yerkes recognises a capacity for ideation, " but," he adds, " contrasted with that of man the idestional life of the orang utan seems poverty stricken. Certainly in this respect Julius was not above the level of the normal three-years-old child." He further proves that they have no linguistic capacity as an attempt to teach them words in relation to their desires completely failed. He concludes that their activities are visual and not auditory, although their powers of phonation are as great as in a human being.

Child psychology has also a great deal to teach us in the matter of acquisition of language, with its three successive stages of noises, crowing and language. The child in the first few months of existence is at the same mental level as the animal when the noises he makes are intended to convey his emotions or his wishes. It is not language yet. His life at this stage, like that of the animal, is all bound up with action. In the later stages, these animal-like reflexes gradually disappear and he develops beyond that stage where his mental life overlapped that of the animal. The next stage is that in which he practises all sorts of sounds, even inventing some which do not occur in the speech of his entourage. It is the period of phonetic experiment. Finally comes the acquisition of words and then of sentences. But at first his words are charged with the concrete nature of the object he sees and it is only gradually that he acquires the power of abstraction and generalisation, when he can form concepts and discover the relationship of these concepts with each other.

Intelligence, then, that is the power of picking, choosing and discriminating and the capacity for ideation, are at the bottom of the existence of language. But experience and memory also play their parts, after intelligence has done its work of picking and choosing. For the process of acquiring and using language can, in a large measure, be compared to the way in which we learn how to drive a motor-car. At first we watch every one of our movements; we have to pay our best attention to the changing of gears, to the acceleration, etc. Everything is conscious. But, according to our varying individual capacity, we sooner or later learn to do all these things automatically, for, if we failed to do so, we would have accidents at every turn. The attention which we ought to devote to watching the actions of other drivers and to the peculiarities of the road, would have to be concentrated on managing the mechanism of our own car. Similarly, the child, in the first stages of the acquisition of his mother-tongue, or the adult learning a foreign language, because they have not reached this " automatic " state, and because they still have to

" remember " the words, i.e. they have to summon them up by conscious effort in their minds, they make all sorts of mistakes, they have all sorts of linguistic accidents. It is clearly seen, then, that first we " pick " and we " choose," using our powers of intelligence to acquire our speech symbols. Our next step is to store them in our memory and to " automatise " them. Although a good deal of our language is thus " automatic," a large portion of it is on a higher plane, and it is the very existence of this linguistic " automatism " which allows of " intellectual " processes to take place, by freeing our attention and bringing into play our associative powers, in order to make new combinations with the old material already acquired and incorporated. We thus attain to the highest form of the mental function, which conditions the original use of language.

Of mental pathology, the one aspect which is of the greatest interest to linguists is " aphasia," which is a disorder of speech. I can only refer and refer briefly here, first to Pierre Marie, of Paris, who revolutionised the old conceptions of aphasia and, in a slightly more detailed way, to the war and post-war work of Head, one of the foremost specialists in this field. He was fortunate in having a large number of cases provided by war conditions and in having in those war patients, young men who were eager to be cured and more willing to discuss their symptoms than the older patients of peace times. The nature of the wounds suffered by the patients gave him a better chance of localising the brain lesions which caused these aphasias.

Basing his deductions on a series of graduated tests of great ingenuity and on the clinical evidence gathered from the application of these tests, Head divides his cases of aphasia into four classes (here I quote the words of his own definitions):

(a) " Verbal aphasia, the characteristic manifestations of which consist mainly of inability to discover the exact forms of words and phrases necessary for perfect external or internal speech, together with want of power to transfer them into written characters."

(b) " Syntactical aphasia, characterised by a more or less gross disorder of rhythm and syntax. The patient talks rapidly, his speech is jargon, and prepositions, conjunctions, and articles tend to be omitted; polysyllabic words are slurred or badly pronounced."

(c) " Nominal aphasia is more particularly characterised by want of power to discover appropriate names or to find categorical terms in which to express a situation."

(d) " Semantic aphasia, characterised by a lack of recognition of the full significance of words and phrases apart from their verbal meaning."

The latest theories are those of Gelb and Goldstein in Germany, which are a development and a confirmation of Head's.

Of the many tests they have conducted on their patients, two will be quoted here, as they will give the necessary basis for their conclusions. The first is the "colour test." Skeins of wool of different colours and shades are placed before the patient. He is asked to pick out the "reds" or the "greens." He is unable to do so. If, however, "blood-red" or "meadow-green" is mentioned, the patient responds immediately. He relates the colour, not to the abstract notion of "red," but to a concrete object, "blood" or "meadow" in this case. The "number" test is also interesting. The patient does not respond when asked what is "one," "two," "three," etc., or to count "one," "two," "three," in succession, but when he is given a row of objects, the sense of the meaning of numbers is revived and he can count. This is somewhat similar in purport, at any rate, to the "clock test" of Head. Here the patient is told that it is a quarter to five and to set his watch. He fails. He is then shown a clock which registers a quarter to five. He reacts properly. I have given a simplified description of these tests, retaining only their essential features. From them it is clear that the linguistic "signs," i.e. the symbolic combination, in the mind, of the picture of the object, on the one hand, and, on the other, the image of the sound-pattern corresponding to it, lose their abstract quality. In other words, does the patient revert to one of the stages noticeable in the process of the child's acquisition of language or to the state of the "primitive mind?"

Gelb has questioned these implications. There are, however, definite points of similarity between the "primitive mind" and some of these symptoms of the aphasis. I have myself shown in my study of the morphology of the *ǂkhomani* dialect of Bushman that their whole linguistic outlook is concrete, both in their methods of expression and co-ordination and in their lack of general terms.

The view which these two co-workers take of aphasia can be summed up briefly. In their system, the essential processes of language form a connected whole, the parts of which cannot be dissocated. They are a "figure, with a beackground" which the outward stimuli excite in the brain, so that, although the clinical picture of aphasia may show a deficiency of one or more of the linguistic processes, it is really the whole of the mental life of the patient which is affected. The reason for the partial picture given by clinical evidence is that the patient may still go on acting automatically, availing himself of that "automatism" of language of which we have already spoken, so that his other linguistic processes do not show any diminution in other directions. According to them, the fundamental cause is the loss of the "categorical" power. This Goldstein defines as follows: "To understand a thing in the "categorical" way means that we conceive, for instance, an object possessing clearly defined qualities as being only a specimen of a group of objects which are similar to it in certain of their features." This defini-

tion comes very near to that of the "power of abstraction" to which we have referred.

CONCLUSION.

I hope that I have succeeded in showing you the extreme complexity of language. We have had to take many aspects of the question into account before obtaining something approximating a clear view. Linguistics is a young science. It is not over 150 years since the first serious beginnings were made in it. Much has been accomplished in this relatively short space of time; much more remains to be done. There are many questions yet to be envisaged and to be solved. For the riddle of man's mind has ever been an elusive and baffling one. But when we take count of the positive contributions of those workers who have realised the overlapping of the linguistic field with their own, we may justly have a feeling of satisfaction, which leads us to express the hope that the same spirit of co-operation will help to clear, in a not too distant future, some of the obscurities which still lie over the science of linguistics.

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ELECTRICITY IN SOUTH AFRICA

BY

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With 1 Text Figure.

Presidential Address to Section A, delivered 8 July, 1938.

It is proposed in this address to review certain aspects of electricity supply and to touch upon the contribution that cheap electrical power may make to the development of the country.

The electrical industry has many points of contact with the sciences falling within the purview of Section A. It has a scientific foundation; indeed, it affords excellent examples of the dictum that fundamental discoveries, which initially appear to be of no more than scientific interest, may subsequently become of immense practical importance. It may be claimed that every branch of electrical engineering had its origin in some purely scientific discovery or other. It is only necessary to mention such names as those of Volta, Carlisle and Nicholson, Davy, Ampère, Faraday, Maxwell, Lodge, Kelvin. Crookes, J. J. Thomson and many others to recall to your minds fundamental researches which now have wide practical application.

Power has been called the handmaid of industry. Modern manufacturing processes all need power in varying degrees. At times, however, power is more dictator than handmaid, for some industries make such enormous demands for power that they are economically successful only in those regions of the world where the cost of electrical energy is very low. For this reason many electrochemical industries have, in the past, developed in countries possessing large resources of available water-power. The production of aluminium is one example of the influence of this factor. For each ton of metal produced, the aluminium furnaces consume more than 20,000 kWh. of energy, the cost of which is thus an appreciable fraction of the total cost of production. At the present time practically the entire output of aluminium comes from places where water-power has been developed. The fixation of nitrogen by the arc process is another example. The energy requirements per ton of nitrogen fixed is said to be about 61,000 kWh., and the process is now in use only in Norway, where water-power is exceptionally cheap.

One might even predict that a country able to produce power at a cost considerably lower than that ruling to-day would tend to attract to itself large industries, provided other conditions were favourable and the power was easily accessible.

In the past, hydro-electric power has been all-important, but of recent years progress in the art of generating electricity in steam power stations has done much to discount the superiority of water-power. Progress made during the last fifty years is indicated in the comparative statistics of two steam-power stations, one operating in Newcastle-on Tyne in 1891 and the other in London in 1938. (Table I.)

TABLE I.

	Station: Newcastle-on-Tyne, 1891.	Station: Battersea. London Power Co., 1938.
Total capacity of generators installed in the station	350 kW.	350,000 kW.
Size of largest unit	100 kW.	105,000 kW.
Maximum operating steam pressure	120 lb./sq. in.	1,350 lb./sq. in.
Maximum operating steam temperature	335°F.	950°F.
Steam output per hour from largest boiler	10,000 lb.	500,000 lb.
Speed of largest generator	73 r.p.m.	1,500 r.p.m.
Steam consumption per kWh. (1)	118·2 lb.	about 8·5 lb.
Coal consumption per kWh. (2) ...	over 21 lb.	0·97 lb.
Thermal efficiency (2)	under 2%	27·63%

Notes.

(1) An average based on the number of units sent out from the station.

(2) An average based on the number of units sent out. Battersea figure being for the year ending 31st March, 1937.

It will be seen that during a period of forty-six years the thermal efficiency of the plant has risen from under 2 per cent to nearly 28 per cent., whilst the coal consumption per unit has fallen from 21 lb. to just under one pound. It may be mentioned that the higher efficiency in the utilisation of coal applies also to practically all the processes for which coal is used. It has resulted in the saving of millions of tons of coal annually, and is probably a minor contributory cause of the present difficult position of the British coal industry.

It will be appreciated that when 21 lb. of coal were used to produce one kWh. of electrical energy, the utilisation of water-power was a more promising proposition than it is to-day. In a hydro-electric scheme, dams, land for water storage, pipe-lines and water turbines take the place of the boilers and steam turbines in a steam station. The capital cost of developing water-power depends on the site, and will be greatly in excess

of that of the alternative steam plant in all but most favourable cases. Consequently, the capital charges on the extra cost of the hydro-electric station may be regarded as taking the place of the cost of the fuel required in the steam station, and if the price of fuel is low, the development of water-power becomes economically unattractive if not actually unsound. We may take it as being highly probable that the most favourably located and topographically formed sites have been already developed. Therefore, in planning a national power supply to-day, coal and water-power will compete on more nearly equal terms, with the balance probably in favour of coal except in countries where coal is scarce or expensive to mine. In this connection it may be mentioned that F. F. Fowle (1), in a paper on power supply in the United States, states that, when ordinary conditions prevail, a steam plant will deliver current at the bus-bars at 4 mils (0·2d.) per kilowatt-hour as compared with 6·3 mils (0·315d.) for a hydro-electric plant. In arriving at these figures he assumed capital costs per kilowatt of capacity of steam and hydro-electric stations to be 85 dollars (£17 14s.) and 250 dollars (£52) respectively. The sterling prices in brackets are on a rate of exchange of one dollar per 4s. 2d. This is supported by a comparison between generating costs in South Africa and those in other parts of the world for which it was possible to obtain statistics. (Table II.)

TABLE II.

Station.	Generating cost per kWh. sent out. Pence.	Output of Station in millions of units per annum.
Steam:		
Klip, Transvaal	0·081	1,350
Witbank, Transvaal	0·140	674
London Power Co. (1)	0·21	2,266
West Midland Public Authority, England	0·33	311
Sydney, Australia	0·96	461
Hydro-electric:		
Kristianasand, Norway	0·083	—
Ontario Hydro-electric Co.	0·091	—
Tasmania (2)	0·17	387
New Zealand, N.I. (2)	0·20	626
Govt. Rate for Industry, Sweden (2)	0·244	—
Galloway Scheme, Scotland (3)	0·3	—
Milan (2)	0·766	—

Notes.

(1) Cost excludes capital charges.

(2) Cost includes certain transmission charges.

(3) The Galloway scheme was completed recently at a cost of £3,000,000. It has a capacity of 107,000 kW. The figure of 0·3d. per unit was published recently as the estimated generating cost when the scheme is in full working order.

It is difficult to obtain accurate information about the cost of generation, particularly in the case of concerns owned by manufacturers for supplying their own factories, and the above table must, therefore, be taken with reserve. It is known that in Belgium, France and Switzerland electricity is produced at a very low figure. Switzerland exports power to all four of her neighbours. One large electro-chemical factory in Norway is said to generate its power requirements at the remarkably low figure of 0·041d. per unit. However, it will be noticed that electricity is produced more cheaply at the Klip station than by the Ontario Hydro-Electric Commission using the waters of the Niagara and other falls. The Klip station has 206,000 kW. of generating plant installed, and extensions are in progress which will bring the capacity up to 424,000 kW., with a probable lowering of the mean cost per unit sent out. Generally speaking, we may expect the cost per unit in South Africa to fall as time passes, but in other countries reduction seems less likely. At Wimbledon the local authority has recently raised its charges for electricity by 15 per cent. to enable it to meet a 30 per cent. rise in the price of coal and other increased working charges. In South Africa we may in time reach the figure of 0·05d. per unit generated.

In view of the improved position of steam power, countries possessing large deposits of easily mined coal are placed in a position favourable to industrial development. If we examine the extent to which this affects South Africa we see, on the one hand, great resources of coal in the Union. Wyberg (2) gives the following tonnages:—

TABLE III.

Coal Deposit:	Extent in Tons.
Proved; calorific value over 11,640 B.T.U./lb. ...	3,697,630,000
Proved; calorific value under 11,640 B.T.U./lb. ...	5,027,460,000
Estimated	15,006,100,000
Undetermined	203,040,244,000
Total	226,771,434,000

The production of coal in the year 1937 amounted to 16·7 million tons, of which 4·6 million tons, or about 36 per cent., were used for electricity generation. The value at the pit's mouth was, on the average, about 5s. per ton. For the same year Great Britain mined 68 million short tons, the value at the pit's head ranging from 13s. 7d. to 17s. 7d., with an average of about 14s. 4d. a short ton. The development of the coal industry in the Union has progressed slowly. The output in 1915 was just over eight million tons, and it has taken 12 years for this output to be doubled.

On the other hand, there are factors which must be regarded as handicaps to industrial development. Our population is too small to provide adequate home markets, and our great distances from the large centres of consumption of manufactured products involve the addition of transport charges to manufacturing costs before our goods can stand side by side with others in the world's market places. These factors become relatively unimportant only if we can show that the commodities we propose to manufacture are in good demand and that we can produce them much more cheaply than they can be produced elsewhere.

Summing up we see that:

(a) There are large resources of coal in the Union, but the development of this asset is proceeding slowly.

(b) Electricity is now produced by the Electricity Supply Commission in South Africa at a lower cost than it is generated at such hydro-electric centres as the Niagara Falls.

(c) The trend of generating costs is a downward one in the Union but probably an upwards one in most other countries.

(d) An abundant supply of cheap power is a vital factor in the economic development of certain industries.

The case as presented is admittedly incomplete, but it appears sufficient to support a plea for action along the following lines:—

(1) An investigation of the economic and technical possibilities of large-scale production of likely commodities in the Union.

(2) The drafting of legislation to safeguard the electricity supply industry in the national interest.

(3) An investigation of electricity production with a view to reducing costs to the lowest possible figure, and

(4) The publication of the fullest information on the power resources of the Union.

Time will only allow very brief statements in amplification of these headings.

(1) *Likely Commodities.*—As examples of likely commodities those used but not made in Great Britain and, in general, those for which the cost of power is an appreciable proportion of production costs, might be considered as likely commodities. Electro-chemical industries appear to offer the most promise.

As a commodity used but not made in Great Britain, calcium carbide suggested itself. One of the principal raw materials in its manufacture is coal, and the power requirement is high, being about 3,500 kWh. per ton of carbide. Two factories, one at Ballengeich, the other at Witbank, are already producing about 20,000 tons of excellent calcium carbide annually. The estimated consumption of carbide in Great Britain is 60,000 tons a year, and all of this is imported, 60 per cent. of the imports coming from Norway. The value of carbide imported in 1937 was £625,000. Recently, however, as a result of the report of the Carbide Factories Investigation Committee, it has decided to erect two factories, in Wales and Scotland respectively, at a cost of £4,000,000. By making use of our cheap coal and electricity we could doubtless land carbide in England at a lower cost than it will be produced there, but this market will be closed as soon as the Welsh and Caledonian factories commence production. The factories are no doubt regarded as of national importance in view of the possibility of treating carbide for the ultimate preparation of nitrates so essential in times of war.

The Principal of the Mineral Resources Department of the Imperial Institute kindly supplied the information that all varieties of metallurgical and electric furnace products in greater or lesser amounts are produced in the British Empire with few exceptions, as, for example, berrylium, pyrotechnic alloys (ferro-cerium), and calcium. Most of the ferro-alloys are produced in the United Kingdom, but many only in small quantities, the domestic consumption being largely met by imports from European countries where, he states, cheap electric power for reduction purposes is readily available. With our resources of chromium, manganese and iron it should be possible to establish remunerative industries for the export of chromium-iron and manganese-iron alloys, besides industries for the export of some of the other items imported into England from European countries where cheap power is obtainable.

Turning to possible electro-chemical industries, aluminium is an electro-chemical product. In its production the energy consumption is about 20,000 kWh. per ton of 2,000 lb. The raw materials are bauxite of good quality, electrode graphite and small quantities of cryolite, fluorspar, etc. Voskuil states that the major sources of supply of bauxite for United States and Canadian aluminium plants are the deposits in Dalmatia and Guiana, and that these are replacing domestic sources Cryolite is obtained from Greenland In 1936 about 50 per cent. of the aluminium produced in the U.S.A. was from imported bauxite.

There appear to be no bauxite resources in the Union, but there are rich deposits in India. Analyses of Indian bauxites from six different districts, kindly supplied by courtesy of the Indian Agent-General, have the composition given in Table IV.

TABLE IV.

Constituent.	Range in the 13 Analyses.	Actual Analysis, Western Chota-Nagpur.
	%	%
Al_2O_3	54·76 to 65·10	60·76
SiO_2	0·08 to 3·01	0·08
TiO_2	2·16 to 10·24	6·04
Fe_2O_3	1·84 to 10·08	4·52
CaO	0 to 0·82	—
MgO	0 to 0·82	—
H_2O (combined)	21·40 to 28·10	29·45

Enquiries indicated that bauxite with a guaranteed content of not less than 55 per cent. alumina and not more than 4 per cent. silica could be purchased at 16s. a ton f.o.b. Calcutta. If this bauxite were to be proved to be suitable for the purpose, an aluminium industry in the Union using Indian bauxite might be a practical proposition.

To avoid transport charges, factories would need to be near a port, with the generating station at or near a coal mine—as, for example, factories in Durban supplied from generating stations on the Natal coal fields. The cost of a transmission line to carry 50,000 kW. at high voltage from the coal fields to Durban would be about £500,000, and at 100 per cent. load-factor would supply 438 million units per annum, sufficient to produce 60 tons of aluminium per day. The capital charges on the line at 6 per cent., together with the cost of line losses, would represent about 0·025d. per unit assuming an annual load-factor of 100 per cent. An advantage of situating the power station on a coal field lies in the possibility of using lower grades of coal (which would be uneconomical if they had to be transported by rail).

The importance of nitrogen products in times of peace and war suggest the need for considering this type of plant. The three principal methods of nitrogen fixation are by the arc process, by way of cyanamide as an intermediate product and by the synthetic ammonia process. The first method is now little used, the last being the most favoured.

The plant for the arc process is simple, and its capital cost is relatively less than that required for the synthetic ammonia processes. The raw material for the arc process is air, the constituents of which are caused to combine chemically to form oxides of nitrogen during their passage at high speed through a powerful electric are between copper electrodes. Rapid cooling of the hot gases from the arc is essential. The final product may be sodium nitrite, calcium nitrate, nitric acid or, by treatment with ammonia, nitrate of ammonia. The arc process might be

worked in proximity to the power stations on the coal fields. Halvorsen (3) states that although the arc process requires more energy for its operation than modern chemical processes; most of this energy is recoverable, and the actual energy consumption per ton of nitrogen fixed is less than that of either the cyanamide or the catalytic ammonia processes. He also points out the possibility of advantageously operating the three processes simultaneously, the acid and steam from the arc process being complementary to the ammonia derived from the other processes. These are matters for consideration by the chemical engineer having in mind the cost of electrical energy.

A plant using the synthetic ammonia process is working at Modderfontein for the supply of ammonia and nitrates to the explosives industry.

While the development of water-power in South Africa is not likely to prove remunerative on its own account, there is much to be said for a policy of damming rivers at intervals and at places where natural storage is feasible. At present water drained from the land floods its way to the sea, carrying with it many tons of good soil. This might be prevented by a series of comparatively small dams located at favourable positions and provided with means for regulating the flow past each dam. The ideal would be to so regulate the flow as to allow normal conditions but to exclude flood conditions. As a by-product of such a policy small water-power schemes might be found worth developing and linking up with steam station networks, or, where this is impossible or economically unsound, the power might be supplied direct to rural communities, by whom it might be used for irrigation or other farming purposes.

(2) *Legislation.*—As electricity supply is unquestionably a matter of national importance, it should be classed as a public utility and placed under some form of national control in all its departments. The establishment of the Electricity Control Board in 1922 was a step in this direction, but the time has arrived for a revision of the Act in order to expand the powers of the Board by giving it control of both generation and distribution. At present its powers are limited, its function being to see that electricity shall be produced in the most efficient manner. It has no control over distribution, which is in the hands of companies or local authorities. Local authorities act subject to the provisions of Provincial Ordinances, but it is possible for them to make excessive profits as distributors and thereby nullify the advantages of efficient generation. To this extent local and national policies are in direct opposition.

Mr. W. James (4) mentions a municipality which takes 14½ per cent. of the revenue from the sale of electricity for the relief of rates. In another case, out of a revenue of £570,400 from the sale of current last year the sum of £71,400 was diverted to the relief of rates. Various other charges permitted by the

Ordinances were made against this revenue. For example, the entire cost of street lighting in the city was defrayed out of electricity revenue and was thus paid for by electricity consumers. The cost of this item was probably greater than £25,000. Then, again, the sum of £5,920 was charged as an annual ground rental for poles erected in the city, and what appear to be unduly high departmental charges were made, bringing the total amount taken from electricity revenue to over £100,000 and probably to nearly 20 per cent. of the total receipts for energy sold. Engineers have more than once drawn attention to this unsound policy, but without success. The only way of checking it is by legislation. In this connection it is interesting to compare conditions overseas with those quoted above. Table IV shows the allocation of the gross surplus (a) from the 378 public authorities controlled by the Electricity Supply Commission of Great Britain, and (b) from the city undertaking referred to above.

The gross surplus is the amount represented by revenue less the sum of working costs, which include rates, charges for repairs and maintenance, and incidentals chargeable to revenue.

TABLE V.

Allocation of Gross Surplus.

1936-1937.	Public Authorities (Great Britain).	City (South Africa).
	%	%
Interest charges (gross)	27·24	34·52
Loan repayment and transfers to sinking funds	41·42	6·94
Net transfers to reserve and renewals ...	5·53	23·99
Income Tax	6·64	—
Special expenditure, including amounts applied to capital outlay	14·52	—
Net contribution in relief of rates	2·45	31·41
Net increase in balances on net revenue account	2·20	—
Transferred to tariff adjustment account ...	—	3·14
	100	100

It should be noted that the 31·41 per cent. shown as contributed to the relief of rates represents only the item of £71,400 detailed in the financial statement, and has no reference to other charges, such as the cost of street lighting, borne by electricity consumers.

(3) *Electricity Production.*—Generating costs fall as the load-factor rises. The load-factor may be defined as the ratio

of the mean demand on the station to the maximum demand. The cost of operating a generating station may be divided into: (i) Capital and other charges, practically independent of the output of the station, and (ii) working expenses, depending on the output of units generated. The total annual charges, P, may be expressed in the form

$$P = a + bn$$

where a and b may be taken as constants (approximately) and n is the number of units generated annually. If N is the number of units which could be supplied if the maximum demand on the station was maintained throughout the year and F is the load-factor, we have $n = FN$.

The actual cost per unit is P/n and

$$\frac{P}{n} = \frac{a}{n} + b = \frac{a}{FN} + b$$

Thus the load-factor affects that component of the cost per unit which represents capital charges.

A typical load curve is shown in Figure 1 (reproduced by courtesy of the Electricity Supply Commission and the City Electrical Engineer. Curve A shows the variation in demand by consumers in the Durban area during weeks in summer and winter respectively. Curve B shows the load generated at Congella Station. The difference between the two curves represents energy generated at the municipal station at Alice Street, together with energy purchased from Messrs Hulett's. The Alice Street Station operates mainly during the peak load period in terms of an agreement with the Commission. Curves C and D show the number of boilers and generators respectively in service at any particular time. As it takes time to prepare boilers for steaming. they must be ready for use in advance of the load, as the load determines the number of boilers actually steaming. To relieve the boilers, to some extent, of fluctuations of demand, steam accumulators are installed at the Congella Power Station to provide a reserve of steam in readiness for sudden changes of load.

The load-factor of the undertaking for the winter week is 48·4 per cent. and for the summer week 48·8 per cent., whilst for the Congella Station the load-factors are 56·4 per cent. and 48·2 per cent. respectively For comparison purposes, it may be mentioned that for 619 undertakings in Great Britain the mean load-factor was about 35·5 per cent.

It is the value of the peak load which determines the capacity of the plant to be installed and the capital charges to be met. As the Alice Street Station supplies some of the peak load, the Congella Station is able to operate at a higher load-factor than would be possible if this assistance was not available.

The supply from Messrs. Hulett's illustrates one manner in which the industrialist may co-operate with the electricity

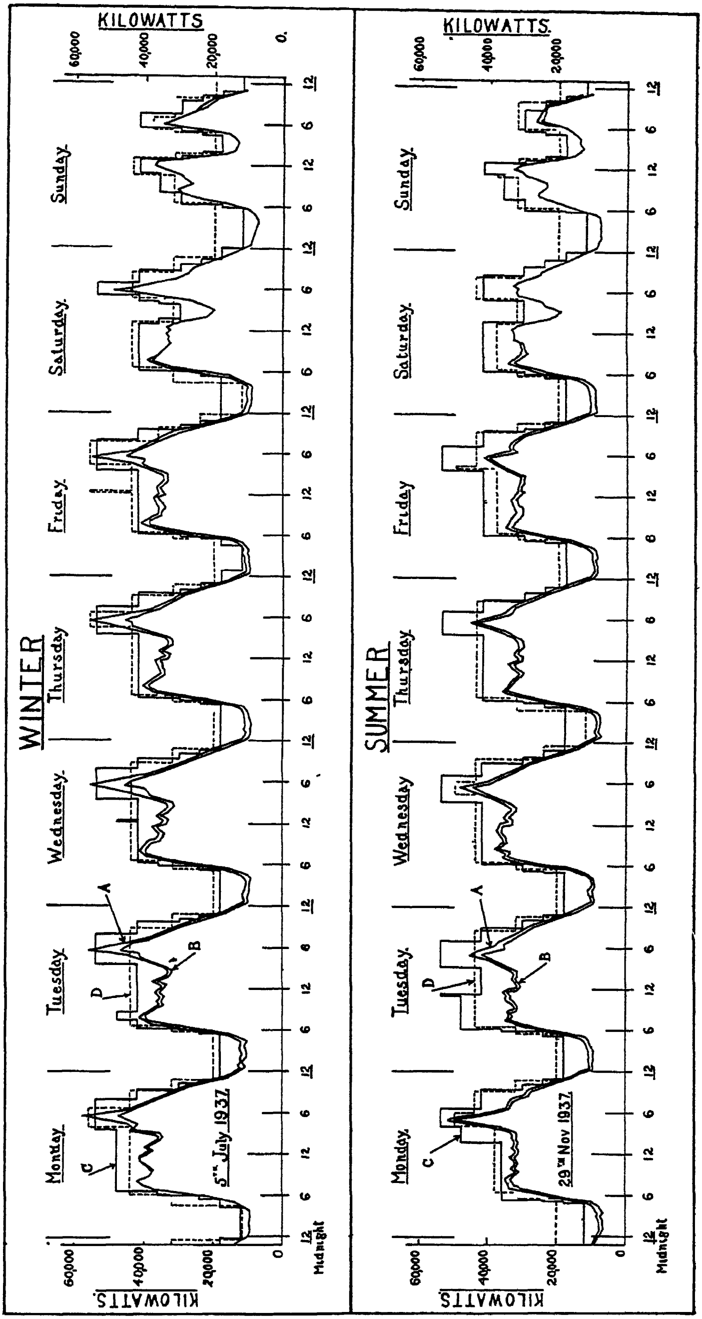
WINTER
KILOWATTS
60,000
40,000
20,000
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
5th July 1937
A
B
C
D
12 Midnight
6
12
SUMMER
KILOWATTS
60,000
40,000
20,000
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
29th Nov 1937
A
B
C
D
12 Midnight
6
12

Figure 1.

producer for their mutual benefit. Messrs. Hulett's require large quantities of process steam at a pressure of 10 to 15 lb. per sq. inch in their sugar refinery. This process steam may be produced in the following manner: Steam from boilers operating at, say, 200 lb. per sq. inch is passed first to turbo-electric generators before it is exhausted into the process mains. This procedure is much more economical provided that a use can be found for the output of the generators. Messrs. Hulett's have an agreement with the Durban Corporation, in terms of which process steam is obtained at the factory and surplus output of the generators is taken over by the Corporation at costs mutually advantageous.

To improve the load-factor diversity of demand is cultivated, and, in particular, "off-peak" demand is sought. Battery charging during the night hours is a good example of off-peak load, and it is inexplicable that so little is done to cultivate the battery-vehicle for the sake of this desirable load. Battery vehicles have been greatly improved during recent years. Mr. J. N. Waite, from his records, shows that, based on a mileage of 10,000 per annum, for a variety of vehicles used by the Hull Electricity Department the total cost of petrol vehicles, including capital charges and working costs, was 50 per cent. higher than for battery vehicles operating on the same services. The Hull area is practically flat, but good results are claimed for hilly districts. For Corporation wagons, for bakers' delivery vans, for the delivery of milk and general merchandise the battery vehicle appears to be well suited, and its general use would improve the station load-factor. It is not necessary to restrict charging to the night hours, a restricted period of one to one and a half hours each day to keep the load off the peak period is all that is necessary.

Where the topography of the area of supply lends itself to the formation of a natural lake, or is otherwise suitable, a water-storage scheme might enable economies to be effected.

Consider the load curve for Durban in Figure 1, and suppose the available plant is just sufficient to deal with the present peak load. If development takes place extra plant will have to be installed. The City Engineer estimates that the peak demand will reach 88,500 kW. by 1943. Additional plant might take the form of new boilers, turbines and switchgear at a capital cost of, say, £20 per kilowatt of generating plant. The new plant would operate under similar conditions to the old, as the load-factor does not usually change materially from year to year. During the peak period all the boilers would be in use; at other times two or three boilers would supply the required steam whilst the others would be standing by with contingent radiation and other losses. Moreover, none of the boilers or generators would operate for any length of time at the particular load for which their efficiency was highest.

In place of extensions to the steam-plant a water-storage scheme might be adopted. During hours of light load sea water might be pumped into a storage reservoir constructed on the Bluff at a height of, say, 300 feet above sea level, and the stored water used to drive water turbines coupled to generators and thereby supply current during periods of heavy demand. By a suitable choice of plant it would be possible to keep the steam plant working at a load in the region of the maximum plant efficiency.

It is not possible to deal fully with this proposition, but a separate paper is in preparation for presentation to another body. The scheme in outline for delivering 30,000 kW. at peak period might involve the use of the following items. Say:

(a) Storage reservoir of capacity about 50×10^6 cu. ft.
(b) Six pumps, each of 7,000 h.p.
(c) six synchronous machines used alternatively as motors and generators with switchgear, each 5,000kW.
(d) Six water turbines.
(e) Six pipe lines with necessary pipework, valves, etc.
(f) Transmission line from foot of Bluff to Congella Power Station.

By using six pumps and six turbines it would be possible to keep the load on the steam plant at a more or less constant level.

The suggested storage plant would supply over 100 million kWh. per annum, and the capital charges would be spread over this number of units.

The economic feasibility of such a water-storage scheme will depend on its capital cost relative to that of extensions to the steam plant, on the cost of coal, and on a number of technical matters.

If the scheme cost £350,000 bearing annual capital and working charges of £83,300 for interest, redemption, extra cost of fuel for pumping, maintenance, etc., the cost per unit for 100 million units supplied from storage would be 0·2d. The average cost per unit supplied from Congella was 0·327d. for the year ending 31st March, 1937, but if extension to the steam plant were made the price might fall to 0·3d. per unit. On this basis the saving effected by the alternative water storage scheme would be £41,700 per annum, neglecting secondary advantages such as those accruing from operating the station at a load nearer to the optimum value.

After a recent visit to the Klip Station, the size of the enormous cooling towers gave rise to a conjecture as to the most economical means of cooling the water after its circulation through the condensers. These towers are capable of cooling two million gallons of water from 38°C. to 28°C. with atmospheric temperature 21°C. and humidity 75 per cent. The capital cost

of cooling towers is high, and the circulation of large quantities of water through them and through the condenser takes considerable power. They are, however, remarkably efficient. It is interesting to note that a refrigerating plant to do the same amount of cooling as one tower would have to abstract 360 x 10^6 B.T.U. per hour and would require a power of about 30,000 kW. to operate it.

Publication.—It would be a useful addition to that excellent publication, "The Mineral Resources of the Union of South Africa," issued by the Department of Mines, if more information was included on the power resources of the Union when next it is reprinted.

Time permits only a brief reference to the influence of electricity on social conditions in the Union. Electricity affects a wide stratum of the people, giving them labour-saving devices and better lighting. By its contribution of electric ignition to the petrol engine it has materially changed transport by land, and electric ignition, coupled with radio-telegraphy, has helped to make air travel as comparatively safe as it now is. In other directions electricity is influencing our social system. In many countries the drift of population to the towns is causing grave concern. This tendency was particularly marked in France, and after the Great War the urgent questions arose of how farming was to survive and develop. Electrification stood out as a remedy against depression, and a policy of subsidised rural electrification was adopted as a means of improving the amenities of farm workers and thereby weakening the attraction of the big cities. By 1937 no less than 95 per cent. of the Communes and 98 per cent. of the population of France enjoyed the advantages of electricity, and in that year alone subsidies amounting to 410 million francs were granted. Just as inventions of the past are behind the great social changes we see around us, so inventions to-day foreshadow still greater changes in the future. Electricity will probably play a leading part in determining these changes.

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SCIENCE IN A PRIMARY FOOD INDUSTRY—THE PRODUCTION OF SUGAR

BY

H. H. Dodds.

Presidential Address to Section B, delivered 7 July, 1938.

I note that Sir James Irvine, in a recent presidential address to the Lancastrian Frankland Society, remarked that there was a good old-fashioned prejudice against using an occasion such as this for a general survey of the field of research in which one is personally interested. I hold, however, on the contrary, that the subject to which one has given by far the greater part of one's attention for many years is precisely the subject, if any, on which one should have something of interest to say.

For myself, therefore, there was no doubt about the subject I should choose for my address to-day, that is the production of sugar, a matter of much scientific and historical interest, as well as of primary importance in modern civilised life, and incidentally of considerable economic importance also to this country.

Outline of Early History of the Sugar Industry.

The history of the world's sugar industry is a very romantic one, associated as it is with the eventful colonisation of those tropical islands and littorals where the sugar-cane, and nature as a whole, though not always human nature, is seen at its best.

For example, H.M.S. "Bounty," on the voyage when the mutiny occurred, whose story has thrilled most of us at one time or another, was engaged in bringing from the South Seas to the West Indies specimens of tropical plants, including some of the now well-known varieties of sugar-cane indigenous to the South Sea Islands.

The earliest beginning of scientific agriculture of sugar-cane and the manufacture of sugar therefrom have not been traced, and Ragozin, in his book "Vedic India," says that no record can be found of a time when the art of manufacturing molasses and sugar by boiling down and clarifying the sap of sugar-cane was yet unknown in India; but there seems to be little doubt that that country (India) was the cradle of the sugar-cane industry. It is the largest producer of sugar in the world to-day, and one of the foremost countries in modern scientific research in the breeding of sugar-cane.

The recently discovered "Arthasastra" of Kontilya, believed to have been compiled about the year 400 B.C., and whose genuineness seems to have been accepted by various authorities, contains numerous references to the cultivation of sugar-cane and the manufacture and utilisation of sugar.

Incidentally, it is stated that sugar-cane is a very difficult crop to grow, being subject to various evils and requiring much care and expense in harvesting. These facts are only too well known to the sugar planter to-day.

We can only speculate on the kind of primitive manufacturing plant used in those early days, but probably there has been little change in essential design to the type of plant used universally by peasants in India and Java to-day.

One I saw a few years ago in Java may be regarded as typical of the more primitive type. It consisted of two vertical wooden rollers, between which the sticks of cane were inserted by hand for crushing, the rollers being operated by a shaft pushed by a pair of oxen walking in a circle. The expressed juice was ladled into a series of clay pots heated over open fire-places, the gradually evaporating and thickening juice overflowing from each pot to the next until finally it was ready to solidify on cooling. It was then poured into baskets containing about 45 lbs., where it crystallised into a hard, solid mass. This exceedingly crude and impure product was sold for 30 cents per basket, equivalent to about 6 lbs. for 1d., about the cheapest sugar of which I have ever heard.

According to W. C. Holden's "History of the Colony of Natal," published in 1855, W. Morewood's primitive factory at Compensation, Natal, in the early fifties was of similar type.

No doubt many rumours of the wonders of sugar and the sugar-cane spread from the East, and many references to sugar may be found in the works of ancient writers such as Herodotus, Seneca, and Pliny, but it is generally supposed that the soldiers of Alexander the Great were the first Europeans to see and taste sugar-cane, somewhere about 327 B.C.

Sugar-cane is a plant that does not lend itself very well to transportation, being propagated in practice from perishable cuttings and not from seed, and possibly the Indians in those days were not very willing to share their knowledge of the sugar industry with others. However, the industry gradually spread from India northwards and eastwards to Southern China and the East Indies, and westwards by means of Arabian civilisation following on Saracen invasion to the Levant According to Deerr there was a flourishing cane sugar industry in Southern Spain well before A.D. 1000. Spain is to-day the only European country still growing sugar-cane, and that on a very small and precarious scale, having been largely displaced by the beet-sugar industry in that country, and entirely so in Italy. The industry continued on the shores of the Mediterranean until destroyed by the Turks after the fall of Constantinople in 1453.

A few years before this, however, sugar-cane had, fortunately, been established in Madeira, the Azores and Canaries, and the Portuguese West African settlements, and from thence, near the end of the fifteenth century, was first transported to the West Indies on the second voyage of Columbus.

The frontispiece to E. O. von Lippman's " Geschichte des Zuckers " gives a graphic glimpse of the sugar industry as it existed in Sicily about the year 1570. The manufacturing equipment is more elaborate than in the the primitive native method we have already glanced at, but is still almost entirely dependent on manual labour with very little in the way of labour-saving devices.

There is in the background being harvested an excellent field of cane conveniently situated only a few yards from the factory, to where it is being transported on mule back.

In the foreground a hefty individual is vigorously cutting the cane into short lengths by means of a broad-bladed knife. The cuttings are shovelled into baskets and carried to the hoppers feeding the mill rollers, which also are hand-operated by means of a lever pushed by two men.

The expressed juice is ladled into open boiling pans heated apparently by wood fuel.

There is no indication of any attempt to clarify the juice or syrup in any way. The concentrated syrup is poured into conical moulds to solidify on cooling. These cones of crude sugar were a characteristic product of the sugar industry until comparatively recent times.

The industry began a new era of development with the discovery of the New World. Many of the West Indian islands, especially Cuba, San Domingo, Puerto Rico, and Trinidad, as well as many of the smaller islands, proved to be an almost perfect natural environment for the crop, and although the mainland of America is not quite so ideally suited as the West Indies, the industry was successfully established also in Mexico and in Central America generally, and also in Brazil, Peru, the Argentine, and Louisiana.

Varieties of Sugar-Cane Concerned in Early Development of the Industry.

Only one variety of sugar-cane was concerned in these early developments of cultivation in Europe and America, and it was not until about the end of the eighteenth century that the introduction of other varieties made it necessary to give the earlier cane a distinctive name. It was a relatively thin cane, typical of its Indian origin, and came to be known in America as " Creole " cane, having been cultivated there for three centuries before any other kind of cane was known. It has now almost entirely gone out of cultivation, but was recently identified by Deerr with the Indian variety known as Puri.

Two main botanical types of sugar-cane originally came into cultivation, one the thin fibrous and hardy type of cane, probably indigenous to India, *Saccharum barberi*, of which Creole, and of more modern canes. Uba, may be regarded as typical, and the other a thicker, more sweet and juicy, but less hardy type, *S. officinarum*, originating in the larger islands of the Pacific, such as New Guinea, Java, Tanna, and Tahiti.

These varieties, of which the Otaheite from Tahiti (eventually also known in various countries by such local names as Lahaina and Rose Bamboo), Black Cheribon (also known as Louisiana Purple), Light Preanger (Crystalina, White Transparent, or Green Natal), both from Java, Light Tanna (Yellow Caledonia) from the New Hebrides, and Badila (NG 15) from New Guinea are representative, found their way to the west from the far east, usually via Mauritius or the neighbouring island of Reunion (formerly Bourbon). These islands have always been important exchange stations for cane varieties.

According to Deerr the first deliberate introduction of a new variety of sugar-cane was probably made by Bougainville, on his circumnavigation of the world in 1766 when he brought the Otaheite cane from Tahiti to Mauritius and Reunion. This was followed a few years later by the introduction of Otaheite cane to Jamaica by Bligh of the "Bounty."

This cane (Otaheite) is said to have doubled the yields of the Jamaican plantations, and even now, 150 years later, is under favourable circumstances still an excellent cane, both in field and factory, and has not changed its character through long years of vegetative propagation. An excellent coloured drawing, which is still an accurate representation of this cane, may be seen in Tussac's "Flora Antillarum," published in Paris about 1801.

Otaheite is, however, very susceptible to the effects of drought and many diseases, and most of the early disasters to the sugar industry in various countries were due to over-dependence on this normally excellent cane. It is now hardly grown anywhere commercially, having been replaced by modern seedling varieties of equal quality and greater hardiness.

Breeding of Sugar-Canes.

It was for long supposed that sugar-cane, through long-continued vegetative propagation, had completely lost the power of forming fertile seed, although in 1858 self-sown seedlings were observed in Barbados, and 1862 in Java.

It was not until 1888 that Soltwedel in Java and (independently) Harrison and Bovell in Barbados produced new varieties of sugar-cane from seed, and so began a line of systematic research that has had the greatest influence on the subsequent development of the sugar industry.

Now most of the tropical sugar-producing countries turn out new seedlings every season by the thousand, of which a select few eventually gain a place in the industry.

As the late F. S. Earle pointed out, this is now being done probably on too large a scale in some cases, so that the resulting seedlings do not always get adequately tested because of the enormous amount of labour required, and no doubt many valuable seedlings are thereby missed.

The two countries who have been most conspicuously successful in breeding new varieties of world-wide industrial importance are Java and India.

In both countries the most successful line of development has been the crossing of established cultivated varieties of sugar-cane with varieties of *Saccharum spontaneum*, a species of wild cane widely distributed in the East. By this means tolerance of unfavourable environment, such as resistance to disease and drought and cold have been introduced into canes of excellent agricultural and manufacturing qualities in a way previously unknown, so that the industry has been greatly improved and stabilised on the technical side by the use of the resulting hybrids.

The first cross of this nature seldom results in a commercially valuable cane, the crossing with an original cultivated variety of high quality—a so-called " noble " cane—having to be repeated perhaps two or three times.

This process of crossing back the original hybrid with a noble cane is sometimes termed " nobilisation " of the original wild cane; the latter is not a sugar-cane at all, but a natural species of cane that has only survived in nature by developing qualities of hardiness.

Recently a wild cane has been discovered in Turkestan by E. W. Brandes, of the U.S. Bureau of Plant Industry, which possesses powers of resistance to cold remarkable for a plant of this genus. It is hoped that it will be found possible to develop from this type varieties particularly resistant to the frosts that occasionally occur in many sugar-growing countries, and capable of continued growth during the long, cool season that prevails in certain sub-tropical sugar-growing countries, especially South Africa and the southern states of the U.S.A. It has been shown that sugar-cane, as now known, can make but slow growth at temperatures below 70°F., even under the most favourable conditions of soil and moisture.

The fertilisation of cultivated canes by wild canes was demonstrated by nature in Java, where an unknown thin brownish cane was found growing among Black Cheribon, a dark purple thick cane. This cane came to be known as Kassoer, and was first regarded as a wild cane, but later was recognised as a naturally formed cross between the Black Cheribon and *S. spontaneum*.

While Kassoer is of no value as a sugar producer it was found to be of great value ultimately for breeding purposes.

This work has been greatly developed at the Proefstation Oost Java, the experiment station of the Javan sugar industry at Pasoeroean in East Java, where new varieties have been developed in recent years that have proved of great value to the industry, not only in Java, but in nearly every sugar-cane growing country.

The distinguishing mark P.O.J. is given to these varieties, and the well-known "Wonder Cane" of Java, P.O J. 2878, has revolutionised the sugar industry, not only in Java, but in many other countries, while P.O J. 2725, though never established in Java, does particularly well in certain parts of Zululand. Both these varieties are grandchildren of Kassoer, and therefore contain one-eighth of *S. spontaneum* blood, to which they owe their hardiness and disease resistance.

Similar valuable work has been done at the Imperial Cane Breeding Station at Coimbatore, in Southern India, first by the late C. A. Barber, and more recently by his successor, T. S. Venkatraman, and his associates. Here also *S. spontaneum* has been of great effect crossed with some of the typical Indian varieties. In this way such varieties of Co. 281, Co. 290, and Co. 301 have been evolved, which have given the sugar industry a new lease of life in Natal and certain other countries.

At this station some remarkable hybrids have been produced of sugar-cane with other graminaceae. Some of the crosses with *Sorghum Durra* Stapf. appear to be of promise for agricultural purposes. More recently an even wider gap has been bridged by crossing sugar-cane with *Bambusa arundinacea Wild*, a species of bamboo common in Southern India.

Similar work has been done in Java by crossing sugar-cane with species of *Erianthus*.

Other countries prominent in this kind of work are the U.S. territories of Hawaii, Puerto Rico, and Florida, also British Guiana and Queensland.

Sub-tropical countries, with very few exceptions, are precluded from producing sugar-cane seed. Even if the plant flowers, which it may do, though much less freely than in the tropics, the flowers are not fertile. It is quite possible, however, for sub-tropical countries to import fertile seed-tassels from the tropics and germinate and raise seedlings therefrom, a practice now being followed in Africa, both in Egypt and Natal.

I have spoken at some length on the subject of sugar-cane varieties, which is, perhaps, not directly connected with any branch of science forming this section of our Association; the excuse must be, however, the overwhelming importance of the subject in the science of cane sugar production, and that after all it has a biochemical end, that is to say the production of

the greatest quantity of sugar per acre, in the purest and, therefore, most easily and economically extractable form.

Development of the Beet Sugar Industry.

It may not be out of place here to say a little of the alternative commercial source of cane sugar, the sugar beet. The manufacture of sugar in this way is of comparative recent origin. It was shown by Marggraf, in 1747, that beet contained sugar, and it was made commercially from that source by Achard 50 years later, but it was not exploited widely until 1812, during the Napoleonic wars, when the blockade of continental European ports by the British prevented the importation of sugar. The alternative appears to have been accepted at first with some lack of confidence, to judge from a cartoon published at the time in France.

Gradually the beet sugar industry became a serious competitor with cane sugar, until in 1899 it first surpassed the latter in production. A neck-and-neck competition between the two continued until the Great War, when many of the sugar beet fields and factories in Europe were devastated, giving the older rival an opportunity to make enormous profits (but not in South Africa, incidentally) and to use some of these profits in making the cane sugar industry much more efficient than before, and secure for some years from serious competition. Moreover, the changed labour conditions and new levels of cost of production in Europe after the war also prevented, for many years, the effective rehabilitation of the beet sugar industry on its former scale.

In more recent years, however, beet sugar has become once more a serious competitive factor, especially with lavish fiscal aid from the Governments of the producing countries.

General Improvements in Agriculture of Sugar.

Both industries make full use of recent general improvements in practice pointed out by agricultural science and research, such as cheaper and better fertilisers applied with fuller knowledge, and improved agricultural implements of every kind. The sugar-cane crop is still harvested by hand almost universally, however; the need for removing the leafy top at a certain point of the stem, which may vary in height above the ground with each individual cane, still requires human observation and judgment, although ingenious alternative mechanical devices have been suggested and are, to a limited extent, in use.

Composition of Sugar-Cane.

I spoke just now of the "purity" of the sugar as it exists in the cane, which is the percentage of sugar of the total solids in solution in the juice, a conception of great importance in the manufacture of sugar.

The principal constituents of the sugar-cane are, the fibre, which is technically defined as the insoluble matter of the cane, and the juice, which includes the water and all soluble substances. The fibre may vary within the limits of 10 and 17 per cent. in commercial cane, depending partly on the variety, but also on climatic and general cultural conditions. The thick type of cane usually has the lower fibre content, the thin type showing a higher fibre content, no doubt, partly because of the greater relative proportion of external surface of woody rind.

The cane sugar, or sucrose as it is termed chemically, ranges from 12 per cent. or less to 18 per cent. of the cane, depending on the variety and its relative maturity. The thick types of cane are normally higher in sucrose than the thin canes, and the peak of sucrose content is reached during the latter part of whatever cool and dry season there may be, in this country usually about September. Another form of sugar found in much smaller quantity, usually about 0·3 per cent., is what is termed reducing sugar, consisting mainly of invert sugar, a mixture of glucose and fructose. This plays an important part during the active growing season of the plant, but should be at its lowest when the cane is harvested. It is uncrystallisable under ordinary conditions of sugar manufacture and accumulates in the molasses or treacle, which is the concentrated mother liquor left after the sucrose has been crystallised out and separated.

Among other water soluble constituents are various organic and inorganic salts, of which the most important basic elements are potassium, sodium, calcium and magnesium, and the principal acidic ions, chloride, silicate, phosphate, oxalate, and other organic acids.

Other groups of constituents of cane juice of undefined chemical composition and intermediate water solubility are, consequently, more difficult to eliminate because of their variable and indefinite physical properties.

Such are various colloid substances, such as gums and albuminoids, and material derived from the protective coating of wax occurring on the stem of the cane. With some varieties, notably Uba, some of these constituents of the juice are of a particularly refractory character at the filtering and boiling stages of manufacture.

Their content in the juice is usually relatively low, but their nature and properties are of more importance than their proportion.

Milling of Sugar-Cane.

The expression of the juice from the cane is, of course, largely an engineering problem.

The cane enters the factory on a conveyor of the endless belt type, on to which the cane is loaded from the railway or

light railway truck or road wagon, in which it is brought to the factory.

The transference to the conveyor is done either by tipping out the contents ot the whole vehicle from a special inclinable platform, or by a mechanical grab or rake.

A comparatively recent development at the carrier, as the conveyor is called, is the provision of one, or perhaps two, sets of rotary knives, which serve to cut the cane into small sections and distribute them more or less evenly over the carrier.

The crushing plant consists of several sets of horizontal rollers, numbering in all from 9 to 20, of almost any size up to a length of 7 feet and diameter of 3 feet.

The cane is subjected to a relatively light hydraulic pressure, from 100 to 200 tons on the top roll, at the first one or two milling units, known as crushers, and which consist of only two rollers each. These express the greater part of the juice and sugar, perhaps 70 per cent. of the total, using about 5 or 6 horse power per ton of cane, the total power consumed by the milling plant being about 12 horse power per ton.

To gain the remaining 20 or 25 per cent. of extractable sugar in the cane after passing the crushers, requires much more severe and elaborate treatment. A comparatively recent introduction is the use of shredders, which, as the name implies, tear the cane into small shreds by one of various suitable devices. The shredded cane can be more thoroughly milled with relatively less pressure, and is more accessible to the practice known as imbibition. This consists in spraying the cane first with the more dilute mill juice, and later with water to enable the mills to extract the sugar more completely from the fibres, of course, at the expense of accumulating a larger bulk of juice for subsequent treatment and evaporation.

The milling units after the crushers consist of sets of three horizontal rollers with their centres forming an equilateral triangle, having its base parallel with the ground. These operate at high pressures, of 400 tons or more on the top roll.

The extracted fibre, now known as bagasse or megasse, eventually passes out of the milling system to the furnaces having a sugar content of only about 2 per cent., and a moisture content of 50 per cent. or less.

In a well-regulated sugar factory in normal process the bagasse forms the only fuel necessary for the factory steam plant, the amount of imbibition water, usually about 30 per cent. of the weight of cane, being regulated according to the heat calories from the bagasse available for heating, evaporating, and boiling down the juice at the various stages of manufacture.

In certain highly industrialised sugar-growing countries, there may be, as in Louisiana, sufficient market for the bagasse

as a source of fibre for making paper or building boards, such as the well-known "Celotex" products. This is only economic, however, if the bagasse can command a price greater than its value as fuel in terms of calories of whatever other local source of fuel may be available.

Treatment of Sugar-Cane Juice.

The raw juice coming from the various crushing units is an unpromising looking muddy liquid containing in suspension the colloid impurities of the cane, small particles of bagasse, and soil adhering to the cane when it entered the factory.

It is first weighed, usually in some form of automatic weighing tank.

In the ordinary process of manufacture of raw sugar for refining in a central refinery, the juice is first sulphited by passing down a tower, where it meets an ascending current of sulphur dioxide derived from burning sulphur. The excess of acid thus introduced in the form of sulphurous acid, together with the acids originally present in the juice are neutralised by the addition of milk of lime. The neutralised juice is then heated nearly to the boiling point, by passing rapidly through a system of narrow tubes contained in a large iron cylinder through which a current of superheated steam is circulated.

The juice is then allowed to settle in open tanks The combined effect of the heat and the precipitation of calcium sulphite and other lime salts results in many impurities being removed in the precipitate. The bulk of the juice is decanted off and forms what is known as clarified juice, a clear pale-yellow liquid.

The settlings are filtered. Until recent years the use of the old plate and frame filterpress was general in the sugar industry, each unit having to be disconnected and laboriously cleaned by hand every few hours, an unpleasant job, wasteful of time, heat, and material.

The tendency now is to use some continuous rotary type of filter, of which the Oliver design, well-known on the Rand, is typical.

The mud from the filter presses, termed filter cake, is a valuable manure and is used on the cane fields. It contains about 1·5 to 2·0 per cent. of phosphate calculated as phosphoric oxide, about 1 per cent. of nitrogen, and 7 to 20 per cent. of lime, mostly combined as the carbonate and phosphate. However, the value of filter cake as a manure can hardly be expressed in the conventional terms of a fertiliser analysis. It contains a large proportion of organic matter in which many of our soils are deficient, and returns to the soil much of what the cane took from it. There are about 16 chemical elements known to be necessary to the life and well-being of the plant, mostly in minute quantities, and in the event of an unsuspected

deficiency of any one of them this unsavoury by-product, filter cake, may be a very important factor in its partial restoration.

The combined decanted and filtered juices are now ready for evaporation. This is mainly effected in triple or quadruple effect evaporators, in which the pressure is so reduced and regulated that the steam evaporated from one body will boil the liquid in the next, because of its lower boiling point due to a higher vacuum. This is a very economical method of evaporation.

Crystallisation of Sugar.

The resulting liquor, now known as syrup, contains about 50 per cent. of sugar and is ready for the final boiling to grain. This is also carried out in a closed pan maintained at high vacuum. When the right degree of concentration has been attained, crystallisation is induced by admitting sugar crystals from a previous operation. The magma so formed, now known as massecuite, is discharged into large tanks called crystallisers, where it remains until crystallisation is complete. The process is hastened by keeping the semi-solid mass in continuous motion by some mechanical device, and in recent years by cooling the tanks.

The boiling of the syrup to grain is a skilled operation, which, until recently, could only be done by workers having years of experience. The process is now, however, much more readily controlled with the aid of electrical conductivity meters. As the boiling proceeds the increased concentration of the salts in solution as impurities results in a greater electrical conductance, up to a certain point at least, when the increased viscosity may increase electrical resistance.

The separation of the sugar crystals from the liquid phase of the massecuite, now known as molasses or treacle, is brought about by the use of centrifugal force. The mixture is poured into shallow cylindrical vessels of about 36 to 48 inches in diameter containing an inner concentric framework of fine copper gauze. The vessel is then rapidly rotated with the aid of an electric motor at about 1,200 revolutions per minute when the molasses spins out through the interstices of the gauze, leaving the sugar in the inner compartment.

Molasses or Treacle.

The molasses is returned to the boiling process two or three times until no more sugar can profitably be crystallised from it, when it is termed final molasses and discarded from the process.

It is mainly used for fermentation as a source of industrial alcohol, but some of it is used as food for stock and some as a manure in the cane fields. It contains, besides uncrystallised sugar, mainly in the form of glucose and fructose, almost all the soluble impurities of the original juice in a highly concen-

trated form. Its considerable content of potassium salts makes it of value as a fertiliser, as well as the bio-chemical changes brought about by its decomposition in the soil.

The quantity of the final molasses amounts to about 2·0 to 3·5 per cent. of the weight of original cane.

Refining of Sugar.

The sugar made by the standard methods of juice treatment and evaporation outlined would be raw sugar, a brown coloured product containing about 97 per cent. sucrose, 0·50 per cent. glucose, and 1·0 per cent. moisture. If sprayed with water in the centrifugals until the sucrose content of the crystals is 99 per cent. or more, a dull white product known as mill whites results.

The product of most cane sugar factories in this and the majority of producing countries is a raw sugar, which may be consumed direct, but is more usually sent to a central refinery. What is known as No. 2 grade, or "government" sugar is a good quality raw sugar.

The refining process usually consists essentially of redissolving the raw sugar and decolorising the solution with boneblack or in some instances with a vegetable carbon, and evaporating the decolorised solution to get the recrystallised product.

There are two factories, out of the 23 operating in South Africa, that make a refined grade of sugar. One of these factories is that of Natal Estates, Ltd., at Mount Edgecombe, which uses the double carbonatation process. In this the cane juice is treated with much larger quantities of lime than in the ordinary process of neutralisation, carbon dioxide being simultaneously added so as to keep the reaction mixture at a hydrogen ion concentration of pH 10·6. The resulting voluminous precipitates bring down almost all the impurities in the juice, so that there is no need to recrystallise the resulting sucrose, which is already of refined quality.

Illovo Sugar Estates also makes a refined sugar, having a small vegetable charcoal ("Suchar") refinery on their premises, in which the raw sugar is treated in essentially the same way as in a central refinery.

The bulk of the sugar made in South African factories is, however, raw sugar, and is either exported or used to a limited extent locally as such, or sent to the central refinery, Huletts South African Refineries, Ltd., near Durban.

Chemical Control of Sugar Manufacture.

The process of manufacture of sugar is subjected to an elaborate scheme of chemical control, the sugar entering the factory in the cane, and its disposition at every stage of the process having to be accounted for.

In South Africa, of every 100 parts of sugar in the cane, about 91 per cent. is expressed by the mills into the juice. This figure is known as the extraction, the balance of 9 per cent. representing the sugar lost in the bagasse. It is evident that the lower the fibre content of the cane, the lower the amount of bagasse, and consequently the lower the loss of sucrose therein with equal crushing efficiency, so that the advantage of a low-fibred cane from this standpoint is obvious.

Unfortunately some of the most valuable canes agriculturally, such as Co. 281, have rather a high fibre, and climatic conditions in South Africa tend towards promoting in any variety, a relatively high fibre content for that variety.

Of the 91 per cent. of the original sugar entering the factory that pass into the juice, 80 are obtained in the form of crystallised sugar, this figure being known as the overall recovery. About 9 per cent. remain in the molasses in uncrystallisable form, 1 per cent. passes out in the filter cake, and a small proportion is lost in various undetermined ways, as for example, by entrainment in the boiling processes. (The condensed waters are tested frequently for traces of sugar to check any appreciable loss in this direction.)

The corresponding figures in certain other highly advanced sugar-producing countries more favourably situated climatically than this, such as Hawaii, Formosa, and Java, show appreciably lower losses in manufacture. However, the figures of South Africa have shown considerable regular improvement during the past few years, a tendency which, there is reason to believe, will continue with the progressive improvement in the quality of cane grown, and improved manufacturing equipment and technique.

The methods of chemical analysis consist briefly of determination of total solids calculated as sugar by the use of the Brix hydrometer, the Brix scale representing the specific gravity of solutions of pure sucrose in water. Sucrose is determined by the rotation of the plane of polarised light in a saccharimeter, which is a special form of polariscope, in which the rotation is recorded in terms of percentage of sugar in water instead of angular degrees. Glucose and other reducing sugars are measured by the reduction of copper from Fehling's solution, using methylene blue as an indicator.

Another optical device sometimes used to determine the sugar, or rather the total solids in solution in the juice, is the refractometer, whereby the concentration of the solution is deduced from its refractive index. Within recent years a portable modification of this instrument, known as the hand refractometer, has come into use for preliminary tests in the field, only a few drops of the juice from a standing cane being necessary to estimate its density, and consequently the relative maturity of the cane.

The acidity of the juices and products at various stages of manufacture is now recorded in terms of hydrogen ion concentration on the pH scale, a conception which has greatly simplified this matter. The original juice of the cane has usually a pH of about 5·0.

The salt content of the juice formerly determined by evaporation and ignition of the sulphated residue, is now frequently estimated by the electrical conductivity of the solution.

PRODUCTION FIGURES.

The capacity of the factories varies enormously, the average for South Africa being 78 tons of cane per hour; one or two factories, however, have a crushing rate of well over 100 tons of cane per hour. The average output of sugar for the season per factory is about 20,000 tons, but one or two make over 50,000 tons, which is more than any factory in most countries, although there are a few factories, such as Central Guanica, in Puerto Rico, and Centrals Delicias and Moron, in Cuba, that have made over three times that amount of sugar in a single season.

The total amount of sugar made in this country is about 500,000 short tons annually (460,000 metric tons). This represents about 7 per cent of the six million metric tons made in the British Empire, and 1½ per cent. of the world total of 29 million tons, of which 18 million tons is now cane sugar.

It is not commonly realised that India is by far the biggest sugar-producing country in the world, the annual output being 1,275,000 tons of refined sugar and 4,200,000 tons of crude sugar or gur as it is locally termed.

The 507,219 short tons of sugar made last season in South Africa was the product of 4,489,022 tons of cane, 8 85 tons of cane being required to make a ton of sugar, by far the smallest quantity ever recorded in this country. This was due partly to the improved quality of the new varieties of cane, and partly to improved factory performance. The area harvested is not yet known, but at the same rate per acre as for the 1936/37 season, 21·27 tons (probably it was somewhat higher) it would be 211,000 acres.

The total value of the sugar produced was approximately 7½ million pounds; just about one-half of the sugar is consumed in the Union, mainly as refined sugar, the rest being exported to Britain and Canada in the form of raw sugar.

Refined sugar is identical in chemical constitution and properties, whether it comes from cane or beet, and normally contains about 99·99 per cent. of sucrose. It is, in fact, the only chemically pure substance commonly met with in daily life. The remaining one part or less of impurities in 10,000 parts of refined sugar consists of minute traces of moisture, glucose, and mineral salts.

Early History of the South African Sugar Industry.

In the brief outline I gave of the early history of the sugar industry there was little or no mention of South Africa, the industry in this country being of comparatively recent development.

There is no indication that sugar-cane is indigenous to Africa, and the circumstances of its first introduction to Natal remain unknown. Nathaniel Isaacs, in "Travels and Adventures in Eastern Africa," in 1831, states that two kinds of sugar-cane were in cultivation by the natives, and quotes two names, obviously intended to be "imfi" and "umoba." Both these words are in use to-day, the first one to denote the sweet sorghum (*Andropogon saccharatus*) and the other for sugar-cane.

Isaacs was a keen and accurate observer, but by no means a scientifically trained one, and it may, perhaps, be doubted whether either of the plants he mentioned were really sugar-cane. Imfi at least could readily be taken for sugar-cane by the layman. R. J. Mann, in "The Colony of Natal," published in 1859, says that sugar-cane was first introduced into Natal in 1847.

If this is so, it was probably imported from Reunion by W. C. Holden, who says in his "History of the Colony of Natal," published in 1855, that he himself planted sugar-cane on a small experimental scale in 1847.

The real pioneer of the industry in this country was Edmund Morewood, who first grew sugar-cane on a plantation scale and made sugar therefrom somewhere about the year 1849. Morewood cultivated four or five varieties of cane received from Reunion, including Otaheite and Creole. His plantation was at Compensation, about 35 miles from Durban.

In G. Russell's "History of Old Durban," it is stated that in 1852 a firm of merchants in Durban imported for sale to prospective planters, 15,000 cane tops from Mauritius, and it was in this year that planting was begun at Isipingo, on the South Coast of Natal. Many varieties of cane were experimented with in these early days, but it was not until 1883 that it was possible to establish the industry on a sound agricultural basis through Uba cane, of which a few cuttings were imported in that year from India by the late Daniel de Pass, of Reunion, near Durban.

This very hardy and dependable cane soon supplanted all other established varieties, and although many new varieties were introduced from time to time, Uba remained almost the only variety to be found in cultivation for over fifty years, having indeed only been displaced within the past few years, mainly by the Coimbatore varieties Co. 281, 290, and 301, or the Javan cane P.O.J. 2725. Very little Uba is now being planted, and at the present rate of replacement, it will have almost entirely disappeared within another two years.

Diseases and Insect Pests of Sugar-Cane.

Sugar-cane has, fortunately, been relatively free from plant diseases in this country, and almost entirely free from serious insect pests. In fact, the only highly destructive insect pest hitherto has been the red locust *Nomadacris septemfasciata*, which has invaded this country for a few years at a time at fairly long intervals, usually 30 years or more. The most recent invasion, beginning in 1935, was cut short by an excellent method devised by the Department of Agriculture, that is, the destruction of the hoppers soon after hatching, by means of poisoned bait, consisting of finely chopped bran impregnated with molasses containing sodium arsenite.

Of recently occurring sugar-cane diseases in this country only two, both virus diseases, are of a serious nature. One of these, mosaic disease, so-called because of the mosaic pattern of alternate light and dark green patches on the leaves, is of world-wide distribution, and very destructive of many varieties of sugar-cane. Fortunately, it has never been much more than a potential menace here, mainly because the prevailing Uba is extremely resistant so that very few cases of mosaic disease have ever been recorded in it, and none in this country.

Many other varieties in the past have become widely infected in this country, infection often being traceable to a perennial grass, *Setaria sulcata*, or Buffalo grass, which is susceptible to mosaic disease of sugar-cane and capable of transmitting it to sugar-cane by means of the insect vector, *Aphis maidis*.

All new varieties released for commercial planting within recent years have been required to prove themselves highly resistant to mosaic disease, at least under our hitherto relatively mild intensity of infection.

The other prevailing sugar-cane virus disease in this country, streak disease, is largely confined to the certain parts of the African continent. The distinguishing symptom consists of tiny chlorotic streaks on the leaves, and in many varieties a restricted growth of the cane.

Uba cane is very susceptible to this disease, which has been one of the principal factors in the deterioration of the variety.

The insect vector of streak disease is the maize leaf-hopper *Cicadulina mbila*.

Dr. H. H. Storey, formerly of the Natal Herbarium, Durban, and now at Amani Institute, in Tanganyika, did excellent pioneer work about fifteen years ago in the study of streak disease of sugar-cane and of maize.

As with mosaic, all new varieties now released for commercial planting must now exhibit a high degree of resistance to streak disease. Of the new varieties now being grown exten-

sively, only one, Co. 290, is not very highly resistant, and that variety shows a high degree of tolerance to the disease; that is to say there is no appreciable loss in yield of cane or sugar from infected plants.

Nowadays, with the greatly increased shipping communication between different countries, and the much freer exchange of plant specimens, the risk of introduction of diseases and insect pests into countries where they were previously unknown has greatly increased. Most countries have learned to cope with diseases and pests with which they have long had to contend, but new ones may take them by surprise very disastrously, especially, for example, the introduction of an insect pest without the attendant parasite that may have kept it in check in the country of origin. Many countries have been obliged to send entomologists overseas in search of natural enemies for their special pests, and in this connection the Giant American Toad, *Bufo marinus*, has done yeoman work for the sugar industry in devouring insect pests in many countries.

These dangers are guarded against as far as possible in South Africa by a strict watch maintained by the customs department against the unauthorised importation of plant specimens, and by placing all sugar-cane cuttings officially introduced in a quarantine glasshouse in Durban, where they are grown in insect-proof chambers from one to two years to ensure that no disease organisms or insect pests accompanied them. This glasshouse is the property of the Sugar Association and an excellent building for its purpose; it was donated to the industry by the late Messrs. D. Fowler and E. Campbell.

Sugar Experiment Station.

After release from this closed quarantine, new varieties of sugar-cane are kept in open quarantine in the field nurseries of the Experiment Station of the South African Sugar Association at Mount Edgecombe, where they are subjected to detailed study over a period of several years. The very few, only eight out of 150 up to the present, that seem capable of fulfilling the particular combination of exacting requirements for this country, are officially released for commercial purposes, and stocks are then built up for distribution to applicants.

The introduction and establishment of new varieties of cane, either from cuttings or fertilised flowers, is only one of the objects of the Experiment Station. Other objects are: the improvement of fertiliser and general agricultural practice as a result of systematic field and laboratory investigation; the study of the control of sugar-cane diseases and pests; the study of technical problems occurring in the manufacture of sugar; the investigation and standardisation of methods of sampling, chemical analysis, and recording applied in the technical control of the factories; the collection and dissemination of general information and statistical records of the sugar

industry and matters affecting the industry; and the maintenance of contact and exchange of information and material with other scientific research institutions in this and other countries.

It forms one of the very few instances in South Africa of an agricultural industrial research institution being financially supported entirely from a voluntary levy on the industry it serves, and not by government, though much scientific and technical help is received from government officials. The present European staff of the station consists of director, five chemists, four agricultural experimentalists, two botanists, two cane inspectors, and two clerks; the present expenditure is about £12,000 a year.

The station, still very small in comparison with those of other sugar industries, was established as recently as 1927, so that South Africa was rather late in coming into line with other sugar-growing countries in this important matter.

The very large experiment station of the sugar industries of Hawaii and Java in particular, have been in existence for many years, during which they have been of the greatest service, not only to their own sugar industries, but to those of other countries as well. In this, as in many other instances, " science knows no political boundaries "; though Java, in particular, has suffered in the past by the free exchange of information and cane varieties with other countries who were their commercial rivals.

Other Scientific Organisations.

Another type of organisation that plays an important part in the scientific and technical life of the sugar industry in this country is the South African Sugar Technologists' Association.

The Society was formed in 1926, and includes practically all the engineers and chemists in the industry, or closely connected with it, as well as many of those engaged on the agricultural side. The principal function of the Association is to hold an annual congress, lasting about four days, during which from 15 to 20 papers are read, dealing with original experiments or with various technical aspects of sugar production. These papers, with full discussions thereon, are published in annual proceedings, occupying about 200 pages. Besides this, the Association is frequently called upon, usually through one of its technical committees, to give technical advice to the industry in various matters.

Similar bodies exist in all advanced sugar-producing countries, while in addition to these there is an International Society of Sugar Cane Technologists of about 600 members, representing practically all cane-sugar growing countries.

This Society holds triennial congresses in various world centres; the control of the Society is vested in general officials appointed for a three-year period from the country, where the ensuing congress is to be held.

These international congresses have been held in Hawaii, Cuba, Java, Puerto Rico, and Queensland, and the next is to be held in Louisiana, U.S.A., in October next. South Africa has been well represented at recent congresses, and four representatives from this country have been appointed to the Louisiana congress.

Any general account of the various scientific influences that have moulded the South African sugar industry would be incomplete without a recognition of the important part that has been played throughout by the sister industry of Mauritius. The manufacturing side in particular has always been largely officered by highly skilled technologists from that island, and the record of progress is largely due to their help.

I have left no time, on this occasion, to say anything concerning the dietetics and economics of sugar, both aspects of great interest and importance in modern life.

Sufficient has been said, I hope, to call attention to the many and varied applications of science to the production of a food commodity that has become of the greatest importance in modern life.

South Africa, like other countries, has certain natural and economic disadvantages in the production of sugar, but these difficulties are by no means fatal, and those countries are the most successful to-day who have most energetically attacked their own particular problems. The outlook in this country is very favourable, especially in view of the continually increasing demand for the services of science.

In conclusion, I would like to take this opportunity of cordially inviting to the Experiment Station at Mount Edgecombe, any members who may be interested to see something of the work of the station.

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FARMING IN NATAL—PAST AND FUTURE

BY

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Presidential Address to Section C, delivered 7 July, 1938.

AREA.

The total area of Natal and Zululand, but excluding East Griqualand is around 35,000 square miles. This is just one-third the size of New Zealand.

Of the 35,000 square miles, 24,685 square miles are open or farm lands; 9,750 square miles are native reserves or locations; 565 square miles are special reserves—total, 35,000 square miles.

CLIMATE.

Though the area is. as stated, only small, yet the climatic variations are very great. This depends, to a very considerable extent, on the altitude, which varies from sea level to 12,000 feet at Giant's Castle.

There is a general rise from the sea board to the mighty range of the Drakensberg, but this rise is not uniform. It is in the form of huge terraces, the first running through in the region of Hillcrest, the second through Hilton, Howick to the spur of the Karkloof, etc.

ALTITUDES.

There are marked undulations within these terraces, and the varying altitudes have much to do with the climatic conditions which are experienced. A little further inland than Mooi River there is the huge shallow-depression which includes Estcourt, Colenso, Ladysmith, Winterton. etc., a very large area situated at a relatively lower level than the surrounding country. This relativity of altitudes is largely responsible for the rainfalls. The higher, cooler ridges get the misty rains which are evaporated again as the sea breezes carry this moisture over the lower and hotter areas. These higher, cooler, moister areas are "sour" areas, contrasted with the lower, hotter, drier areas which are "sweet" veld areas. The sweet veld areas are generally "thorn growing" areas, and these may be at sea level or over 4,000 feet, whilst sour areas may be much below this. Thus in a journey by the main road from Durban there is sweet veld or thorn areas encountered at Pinetown. At Kloof, Gillitts, Hillcrest, there is sour veld. This continues through Bothas Hill, Inchanga, to

Harrison, and then a general downward trend to Umlaas Road finds thorn veld beginning. Nearer Pietermaritzburg in the M'Pushine there is almost solid thorn, and this extends to the eastern boundary of the city. From the west of the city sour veld is experienced until beyond Mooi River, where a sudden drop shows the sweet veld again. Or via Greytown, there is a slight fall to Albert Falls, almost thorn country, a climb over the next ridge, sour, and a drop down to New Hanover, sweet again; from there on until beyond Greytown on the Dundee road there is sour veld, only to drop into the thorns again down to the Tugela. The road to Kranskop keeps on the ridges and traverses sour veld country.

It is not absolute altitude above sea level which is responsible for this but relative. Thus at 2,000 feet Hillcrest is sour. At 4,000 feet Estcourt is thorn country.

As indicated, this relative altitude determines the rainfall. The ridges are high rainfall areas, the hollows are lower rainfall areas. The low rainfall areas lying often in depressions or basins are hot in summer, and likewise very cold in winter, though a very dry cold.

RAINFALL.

This is of two kinds, the gentle rains blown inland from the Indian Ocean and the tropical thunderstorms which have their main origin over the mighty Drakensberg. The former rains are generally the earlier, and the more beneficial, being soaking in character and not tending to rapid run off and consequent erosion.

Along the coastal belt there are often very beneficial showers through the winter months, though the largest precipitation occurs from October to March inclusive. This six months period has approximately 74 per cent. of the average annual rainfall, whilst June, July and August experience only 7-8 per cent.

Averaging the bulk of Natal, but excluding the coastal rainfall area, almost 83 per cent. of the total rain falls in the six months before mentioned; June, July and August having only about 4·5 per cent. Hence it will be noted that there are really two seasons wet and dry corresponding to Summer and Winter. These facts will be borne in mind later on when dealing with crops and live stock. Farming practices and live stock management have to take full cognisance of these facts, and sound systems of crop production and live stock management must be built up on these.

The actual rain in the coastal belt averages a little every 40 inches, whilst in the sour veld areas in the Midlands it is about 35 inches, and in the sweet veld areas 25 inches to 30 inches.

The coastal area is almost entirely frost free, though just occasional touches of hoar frost are experienced. In the Midlands night frosts are common from the end of May or beginning of June until August. These vary in their intensity according to the exposure and whether the area lies in a hollow or not. Low lying

areas, and particularly those where the atmosphere becomes stagnant, have the most frost. It is seldom that the ground is frozen more than the merest surface. The night frosts remove most of the moisture out of the atmosphere, and deposit it as hoar frost on the vegetation in these low-lying areas. These have more moisture in the winter time than the hillsides.

Spring rains, often accompanied by snow falls on the Berg, are responsible for late frosts in the Midlands even into the month of October. Such frosts may check the spring growth of grass, and cold spring rains unfavourably affect live stock, becoming somewhat thin at the end of the winter.

The maximum temperatures seldom exceed 100°F. in the shade. In a city as Pietermaritzburg, there are probably not half a dozen days a year where the shade temperature reaches the three figure mark. Sweet veld areas, on account of their relatively lower altitudes, have higher summer temperatures than the sour veld ridges. Temperatures running into the 90's are common, whilst 80's are common in the sour veld through the summer. The average figures for a 10 year period at the School of Agriculture, Cedara, altitude 3,700 feet in the sour veld are:—

	Shade. Average Maximum °F.	Shade. Average Minimum °F.
January	76·75	58·39
February	76·66	58 16
March	73·87	56·45
April	72·17	51·71
May	68·22	45·34
June	65·98	40·60
July	65·83	39·56
August	69·09	44·03
September	71·37	48·18
October	72·36	51·52
November	74·80	53 91
December	76·07	56·08

	Mean Annual Temperature. °F.	Mean Warmest Month. °F.	Mean Coldest Month. °F.
Dundee, 4,099 feet	64·3	72·4	52·4
Ladysmith, 3,284 feet	66·7	77·0	52·4
Weenen, 2,841 feet	66·4	77·0	52·0
Pietermaritzburg, 2,218 ft.	66·6	73·4	57·6
Durban, 260 feet	70·8	76·6	64·6

These figures give a general oversight only of the climatic conditions which are part and parcel of our farm ecology. Reference in passing should be made to the incidence of hailstorms, these devastating experiences which cause much anxiety. The worst hail-storms usually occur towards the end of summer,

when it is impossible to replace the crops which may have been destroyed. Where storms are experienced earlier in the season, a readjustment of the cropping plan is often possible, but late storms are most destructive, and there is little opportunity to overcome their ravages before the dry winter period begins.

The Geology of Natal.

Whilst the soils of a country are influenced by the geological character of that country, climatic and other conditions have played an important role with regard to the plant food which is left in the soils, whatever their origin. Thus, there is a considerable difference between the sour and sweet veld even when they fall on the same geological formation.

There are five important series of rocks running lengthwise through Natal. They are:

(1) Granite and Gneiss and Metamorphic rocks.
(2) Table Mountain sandstone.
(3) Dwyka.
(4) Ecca Shales.
(5) Dolerite caps and intrusions.

(1) *The granites and gneiss and metamorphic rocks.* These run from Port Shepstone on to Umzinto. They are found around Inchanga and on to Mapumulo, Kranskop and the higher land running on to Entumeni. These give fairly satisfactory soils, though granites may also be sandy, with more potash, lime and phosphates than the soils derived from sandstones. Stock grows out fairly well on these areas.

(2) *The Table Mountain sandstone* is found right along the Coast from Port St. Johns to Port Shepstone. Then from the vicinity of Highflats, passing a little nearer the coast than Richmond, Camperdown and on up the North Coast just missing Verulam, through Stanger and on to Eshowe, with a small outcrop near Melmoth.

These areas tend to be hot and dry with a shortage of mineral constituents for the growth of live stock. They are really hungry districts, and call for great attention to the conservation of and building up of soil fertility.

(3 and 4) *The Dwyka Conglomerate and Ecca Shales.* In the Midlands of Natal, from Port St. Johns between the Table Mountain sandstones and the coal measures, in a somewhat narrow strip extending right through to Pietermaritzburg.

These Ecca shales are of a very poor nature from a farming point of view. The School of Agriculture at Cedara is situated upon Ecca shales capped by Doleritic boulders. The natural fertility is very low and the indigenous herbage poor with low mineral content so that cattle are " Bone Chewers " under normal conditions.

It is under these climatic conditions and on soils derived from these geological formations that the farming is carried out in Natal.

The farming is very largely adapted to the ecological conditions. Sugar cane could only be grown in the Coastal belt where there is an absence of frost, and where the higher average temperatures are most favourable to its growth. The dry season aids in ripening the cane and increasing the sucrose content.

The growth of the wattle, with its 300,000 acres, is situated in areas where the misty and heavy rainfall conditions favour rapid growth of the trees. Valley bottoms generally have the wattle killed out in them due to heavy night frosts. The bulk of the wattle area is, therefore, on the tops of the hills and in the rolling country.

The general dairy farming in the Midlands accords well with the seasons also. The dry winter is very favourable to stock, and with the shelter that can be easily grown, stock need suffer no hardships due to exposure.

The dry winter also influences the plant food in the soil. There is no leaching of plant food from the soils in the winter. There is no puddling or trampling of the physical character and its resultant spoilage in the dry winter. The condition of physical drought which enforces a cessation of soil activities is very beneficial, as the activity, when rain falls, is soon in full swing again. The periodicity of rest and activity is here well exemplified, and favours farming operations.

It has frequently been maintained that the coastal belt, due to the more severe endemic diseases such as red water and gall-sickness, is not suited for cattle, and that they can only be moved into the coastal belt during the winter months when tick life is at its lowest. There are many examples, however, of cattle transfers at other times and where dipping facilities are provided, and where this operation is consistently and thoroughly carried out, the transfers have been very successful.

Sheep farming has been bound up with climatic conditions too, but blue tongue inoculation and a fuller knowledge of parasitic worm control are enabling sheep to be farmed in areas where sheep-farming was not looked upon with favour previously. Horse sickness does not hold the same terrors for farmers to-day, and the preventive inoculation will be responsible for many more horses in Natal Agriculture in the future.

Our Soils.

The *wear and tear* on our soils is definitely too high. Our farming systems have not given sufficient attention to lessening this evil, whether on our arable lands or on our natural grazing grounds.

From the undulating and rolling to even steep nature of the country, it is evident that the run off of tropical rains must be rapid. Such run off carries with it large quantities of surface soil, not only as sheet erosion, but also as gully erosion.

Largely due to incorrect grazing systems on the veld, and only partly to incorrect veld burning, the grass cover has been thinned down, and to-day there is a very large per cent. of the total area of our grass veld which is entirely bare, and where this erosion or wear and tear is constantly taking place between the tufts of indigenous grasses.

The ploughing of lands year by year, and so burning up the organic matter of the soil, with no attempt at its replacement, renders our arable soils incapable of rapid absorption and retention of rain. The crumbly nature of the soil which permits this to happen has been broken down, and in many cases impalpable powder results. This will not allow of rapid absorption, and rain water begins to run and erosion takes place. To-day our rivers run red with the life-blood of our land after every thunder shower.

Such losses of valuable soil rapidly reduce the total volume of our soils, and the lost portion is the most valuable. The arable soils have become thin, more and more composed of raw, undeveloped subsoil with low crop-growing powers.

Insufficient attention is directed to the maintenance of a good supply of vegetable matter in the soil, and so the crop-growing capabilities and stock carrying capacities steadily depreciate.

This is not as it should be. It savours of mining the soil and not soil building, and largely results from the growing of one type of crop to the exclusion of crop rotations whereby restoration of the organic matter could be made, and a check imposed upon the diminution of the volume of the soil.

Our Crops.

It is regrettable that there is no acreage of the natural grazing grounds, nor of the amount of established pastures published.

Grass is our most important crop, but this has yet to be realised by many of our primary producers. Of our grass crop, the indigenous veld is of the greatest importance by far, but greater calls have been made upon it than it has been capable of responding to. The veld is truly important, and calls for a much greater knowledge of its reaction to man, the fire stick and the grazing animal, than is commonly possessed to-day. It is relatively extensive rather than intensive. Its carrying capacity is not high, neither for quantity nor quality live stock. Yet it has borne the brunt of grazing all farm live stock, and there have been sold off the veld more live stock and live stock products, milk, beef, mutton, wool, etc., etc., than from the cultivated lands; yet to the veld there has been returned practically nothing in the way of plant food.

The veld soil has thus been impoverished; and as a result the flora has changed to hardier grasses able to exist in poorer conditions than the original grasses could. This change has been accelerated by lack of proper management whereby the best grasses have been consumed and eaten out, and they have never been given a chance, by deferred grazing, to re-seed and so re-establish themselves.

We have retrogressed to poorer and inferior types at the same time that we have tried to better our live stock. When grass species have failed their places have been taken by weeds of different sorts, and there are many places where weed invasion has assumed serious proportions. Hence, generally speaking, our grazing grounds are in a poorer condition than they ought to be. There has been far too much grazing of the whole veld all the time, and far too little rotative and deferred grazing practised. Unless the latter system is introduced more and more, the veld will deteriorate still further, and the production of animal products therefrom will become gradually less in spite of attempts to maintain yields of live stock products through the use of improved sires.

ACREAGES OF VARIOUS CROPS.

(Agricultural Census No. 15.)

	Morgen.
Barley for Grain	285
Oats for Grain and Forage	13,382
Rye for Grain	1,950
Wheat for Grain	882
Maize for Grain	187,723*
Kaffircorn for Grain	7,182
Potatoes	4,396
Tobacco	374
Ground Nuts	935
Lucerne	1,077
Teff Grass (Census No. 11)	5,214
Tea	2,139

* Maize total, 187,723 morgen. Total other crops, 37,816 morgen.

Leaving out of account sugar and wattles, the onesidedness of our crop production is evident from the foregoing figures. Even when kaffircorn is totalled with maize there are six times as many morgen under maize and kaffircorn as of all the other crops. Leaving maize alone, and linking kaffircorn with the other crops these form only one-fifth of the area planted to maize. It is perhaps unfortunate that a wider range of crops is not listed, as there are no classes for cowpeas, soya beans, root crops as choumoellier, swedes, turnips, kale, rape, etc. The absence of these crops from the listed totals would indicate their relative unimportance, and this throws into further prominence the dominant place that maize takes in our systems of crop production. The census figures also show that the yields per acre or

per morgen of maize are very low, being 6·2 bags per morgen in 1934-35; 7·3 bags in 1937-38.

This class of production cannot be profitable, and an improvement in the production per unit of area should be sought for. This may come about through changes in our farming systems where temporary pastures are established for a period of three to six years, and then brought under cultivation again, bringing back the organic matter to the soil and restoring its former crumbly nature.

Concerning our crop production to-day, we do not utilise fully the rain which falls. Many of our arable crops can only utilise about half the rain that falls due to their short life, and the time of their planting. Our cropping systems need to be amended to make greater use of our rainfall, for which we pay nothing.

The wear and tear experienced in our soils leaves, as indicated previously, an impoverished and only partially formed soil. To counter this, our fertilizer applications must be heavier, and directed towards development of root systems in our crops. This is one of our chief failures in our farming to-day, viz., the use of very small quantities of artificial fertilizers and the preparation and use of too little kraal manure. Much larger yields and greater profits per unit of area would be secured, both on arable and pasture soils, by the use of increased quantities of the correct fertilizer for the crop to be grown. The law of increasing return is operative in many of these instances.

Farmers in Natal are generally live stock farmers in some degree, and have followed the wise course of marketing their crops through their live stock. The following figures indicate the relative small losses in animal products compared with the sale of crops.

	Lbs.	Nitrogen.	Potash.	Phosphoric Acid.	Lime.
Maize, 30 bushels ...	1,680	28	6·5	10·0	5
Stalks, etc.	2,208	15	29·8	8·0	—
	3,888	43	36·3	18·0	—
Meadow Hay, 1½ tons	3,360	49	50·9	12·3	32·1
In 1,000 lbs. of various animals and their products:					
Fat Ox	—	23·26	1·76	15·51	17·92
Fat Lamb	—	19·71	1·66	11·26	12·81
Wool, Unwashed ...	—	54·00	56·20	·7	1·80
Milk	—	5·76	1·70	2·0	1·70

Without dealing in too great a detail with the question of fertilisers, it should be remarked that the use of inoculated legumes does not occupy as important a place as it ought to in our cropping systems. The ability of these crops to gather cheap atmospheric nitrogen and to attack insoluble phosphates in our red doleritic soils needs to be utilised to a greater degree than at present.

Adsorption.

There is a rather serious loss in quite a number of our areas due to the excessively large quantities of iron and alumina in our soils. The addition of soluble phosphates to such soils results in their hold-up by adsorption, and their loss to the crop; and hence their elimination from the circulatory system of plant-food on the farm.

Crops on the average Dairy Farm.

The average dairy farm can produce a wide variety of crops. The simplest, extensive method is where the greatest reliance is placed upon veld pasturage and veld hay and dry maize stalks in the winter. Happily this type is being rapidly squeezed out.

Contrasted is the complex intensive method where veld carries only dry stock or such extensive animals as working oxen; where established pastures such as Kikuyu, Paspalum, Rhodes, Napier Fodder, Brachyarias, Panicums, Rye grasses, Cocksfoot, Fescues, Digitarias, etc., either in pure culture or mixed with clovers form the main grazing crops on which quality live stock can be maintained.

These pastures are maintained at a high level due to annual fertilisation. They are supplemented by grass and maize silage, hays from the grasses, and legumes maize stover, roots as rape, turnips, swedes, kale, chou moellier or marrow stemkale, sweet potatoes, algerian oats, mangolds, etc. Thus, there exists scope for the diversification of the cropping system, and its balance with the varying classes of live stock kept by the farmer, There is no need to-day to be a single crop farmer.

Specialised crops grown which have little associated livestock with them are wattles, with 300,000 to 500,000 acres, sugar cane (including Zululand) about 350,000 acres and considerable acreages of forest trees. Many parts of Natal are well wooded, and there are other areas where the trees are scarce, and plantations could be established with benefit to the farms and stock. Both of these crops can return much vegetable matter to the soil. They are both slow in their return, particularly the tree crops. The economic lag is great.

A very pleasing feature at the present time is the great interest which is being directed to improved pasturage. The low yielding nature of our veld, whether for quality or quantity, is forcing attention to the possibilities of higher quality live stock and greater quantities of such live stock. Research work in both the sour and sweet veld areas has indicated vastly improved possibilities in both these directions. There is no doubt whatever that we can farm on a much higher scale than at the present.

Pastures are possible from the coast to the high veld. Different genera and species of grasses will be found to fit the varying conditions. The same basic scientific principles of establishment and management will be required under the varying ecological conditions.

Live Stock.

Turning now to the live stock aspect of farming in Natal, it will be found that this is very diversified. Natal has several bacon factories, several condensed and/or dried milk factories, and many creameries. Dairy cattle with pigs and poultry supporting are found on most farms. Many farmers pay a great deal of attention to beef cattle also. In the northern parts, there are more sheep, farmed largely for wool.

The live stock question has been largely governed by Endemic live stock diseases.

Horse sickness has, up to the present, been the factor governing the use of horses on many of our farms. The risk factor was too great to allow of the use of horses as draught animals, and oxen took their place.

Blue tongue in sheep largely prevented sheep being farmed at the lower altitudes.

Biliary fever in horses; red water and gallsickness in cattle as well as East Coast fever have all played very important roles with regard to our live stock development. They have enforced systematic dipping of all cattle; frequent inoculations, etc., all of which the live stock would prefer to leave out. They have been vitally essential hitherto.

Control of these troubles will result in rapid changes with regard to our livestock, both as to quantity and also as to quality. It needs to be realised that there should be a judicious admixture of classes of live stock on our farms to make the fullest use of what the farm produces. Sheep will eat weeds left by cattle; a combination of equines and bovines give better pasture control than either alone; pigs and poultry consume dairy by-products with profit, and utilise foodstuffs which would otherwise be lost.

The production of live stock products needs to be looked at from the aspect of the production per unit of area. From this view point the productions are low. There is much scope for amelioration in this direction. Whilst low yielding live stock, whether dairy cows, beef cattle, sheep, etc., were balanced with the extensive veld pasture, they cannot maintain their position on improved pastures. Intensive animals must be found on intensive pastures, and in no other place.

Present Market Position.

The markets for our different farm products are very diverse. For sugar, the South African market is practically reserved to us. Yet about half the total manufactured sugar is sold oversea. The total production is approaching the half million ton mark. There is a very large potential market amongst the native population, but the development of this market is wrapped up in the general economic welfare and wage earning capability of the natives. The rise in the price of labour, or rising wages, will

have a much greater effect than an increase in the consumption of sugar. Many of our products are subject to seasonal surpluses and sometimes deficiencies, and with such conditions, the building up of stable export to the world's markets will present serious obstacles. Greater production is necessary to allow orderly marketing along soundly developed methods. This applies to dairy products, beef, milk, lamb, etc. Definite markets exist for wool, citrus, wattle bark, etc., though extension of these markets is often desired.

In looking at present production and marketing, sight must not be lost of the production of the native peoples of the Province, nor of the market which they offer for the products of European farms. They have constantly formed a market for maize, kaffir-corn, scrub-cattle and beef, etc. It will be interesting when considering developments which must be looked forward to as likely to happen, whether this market will remain or not. Our vision must not be a " close up " one only. We must endeavour to look forward as this will influence very markedly our planning of our farming systems for the future.

The Future of Our Farming.

The climatic and geological factors which govern production to-day are not likely to change in the future. The use we make of our climatic factors will probably alter. We shall utilize the rainfall to a greater extent through increased acreages of improved permanent grass land, and by adding fertility in the shape of plant foods to our soils, we shall still further increase the use we make of our rainfalls. Lower rainfall areas will not grow maize where this is a risky crop, but kaffircorn, or even revert to grass-land suitable for ranching purposes or extensive production only.

By means of surveys definite farming systems will be established for the different areas, and according to the results of these surveys there will develop zones of production which should aid orderly marketing. There would be no compulsion for anyone in the particular zone to farm only those crops, stock, etc., which have been recommended in the survey. The survey would form the guide book to the area. This will form the basis of the value of land which must be determined by its earning capacity in producing primary products.

Our Soils.

Closer study of our soils whereby we possess further knowledge of their micro biological characters, will give us added control of them. We need to know about free nitrogen fixation in our warm arable soils. We need to know about the organic matter of our pasture soils and whether we can " cash " the added value of our pasture soils without recourse to the plough. This knowledge can only be obtained through studies of our actual soils under the existing climatic conditions which we experience. A full understanding of the effect of dry desiccating winters upon

the soil flora will aid us further. This knowledge cannot be longer delayed. It is fundamental, and lies at the very base of a successful live stock industry—without which profitable production cannot continue.

It will probably be found that sound soil sense, building up rather than mining, will improve our animal health as it will their growth and yielding and reproductive powers. All agricultural operations follow in a cycle or chain, and the fundamental items must be sound if we would see a sound system follow. Increased knowledge of our soils must be obtained. We cannot continue to lock up phosphates in the soil: we need to gather more nitrogen which is free for the collection and to bring this into circulation in an organic form, from our soils, through our crops, to our livestock and back again to the soil, stopping up leaks by the way.

In the future it is our farming systems, our livestock management, veld control, etc., that will have to prevent soil erosion. Farming systems which bring this evil in their train will have to be discarded, and only those which are inherently sound from the many necessary viewpoints will be found to persist. The farmer must preserve the soil and increase its volume all the time. This is his inheritance, which he holds, in trust only, for future generations. He should not alienate or mortgage any of this inheritance.

Our Crops.

As increased attention is directed to our soils, to increase their volume and augment the plant food they contain, so must our crops be able, through their improved germ plasm, to make the fullest use of these. There is need for a finer understanding of the conditions and relationships between soils and crops to enable the best balance to be achieved. It is not from our grain crops that the greater development will come, though by obtaining better germ plasm and by increasing the spread of this through the province, yields can be increased considerably at no increased cost of production due to cultivations, etc. It is from the grasses that we look for increased production of animal products. We are only just at the very beginning, only at the letter A in our knowledge of pastures and what they can produce in Natal. We have enormous tasks ahead of us in trying out other grasses; of securing sound scientific knowledge of their seed production, seed viability, building up of strains of superior producing capacity, of checking up on seasons of growth so that we can stretch the growing season out over as long a portion of the twelve months as possible. There is much to be done also to secure cheap nitrogen for our pastures. We have to see to it that, slowly perhaps, yet with absolute certainty, we are inoculating increased area of pasture land year by year with the nodule organisms so that we can grow clovers in any of the soils at any time without recourse to seed inoculation.

This nitrogen question in our improved pasture is more important than all the others. It is the key to the success of pasture establishment and permanence, viz., a constant supply of available nitrogen to the grasses in the desired grass-clover combination. When this phase of pasture work is thoroughly understood and success therein achieved, we shall have advanced to the position where temporary leys are possible and where we can rest land for a period, to allow it to regain its physical characters before cashing the soil fertility that the pasture has accumulated.

Not only in our pastures but in our cultivated crops must inoculated legumes take a greater place and play a greater rôle. Crops which leave the soil richer in certain ingredients, and which make others more available, must play their part in reducing costs of production. There will be legumes for all our climatic conditions, and legumes must be as sure as any other crops, and pure lines and strains must be developed. These will result from intensive search for superior germ plasm greater crop yields, not in one kind of crop but in all our crops—grass, cereal, root, etc. Just as there have been improvements in our sugar cane varieties, so shall we improve our wattle trees, and all our crops which combine the raw, simple substances of nature into the complex compounds required by our stock and ourselves.

For the reason that permanent agriculture is dependent upon crops and livestock and not crop production alone, there must be more crop consumed by livestock and only livestock products sold. Thus shall we minimise the loss of fertility from our farms. Coupled with increased doses of fertiliser until the last dose just pays for itself shall we build up our production, but not at the expense of depleted soil fertility nor exhausted farms. When we have learned how to produce quality grass, we shall have to learn how to conserve the surplus or peak growth by dried grass methods or ensilage.

These improvements in our crops may not be the end. They may bring other changes in their train, and so there will ever be the necessity for marching forward. High sucrose content of cane is reducing the acreage of sugar cane and bringing a new problem into the sugar belt. This problem demands immediate attention.

Our Livestock.

The problem has been presented, as I believe, from the correct perspective. Soil and crops must be considered before livestock. Livestock inheritances can only expand and unfold in a correct environment. Looking, as we are, for livestock improvement, we cannot achieve this in a deteriorating or standstill environment. In the future our farmers must realise that a better sire movement can only attain success in a better environment. There must come about, therefore, a better balance between environment and inheritance. So far, the greatest effort has been made by endeavouring to obtain every-

thing from better sires. It means less perspiration, but is not compensated by increased inspiration!

Primarily, as we improve the environment for our livestock, as we make full provision for winter feeds of the right kinds and quality, and balance our crops and pastures with our livestock numbers, so will the animals respond. They will increase their production to the capacity of their inheritance. At this stage there will be a balance between inheritance and environment.

We shall not be prepared to stand still on *this* point, however. I have indicated a future with improved crops, yields, etc., creating a finer environment for our stock. When this is obtained, there will be the striving for better inheritances in our livestock. Just as there was indicated a search for superior germ plasm in our crops, so must there be a search for superior germ plasm in our different breeds and kinds of livestock.

Nor will it be sufficient to search for and find this better inheritance germ plasm. If we get it in one animal only, that will be of little use to us. We must know more about the laws and ways in which this material is inherited. How do the various individual characters of which the superior animal is made up behave in inheritance?

Our conception of the animal *as a unit* must be altered, and we must approach the problem from the unit character aspect. Thus a single animal may have many unit characters which must be studied. This will be slow but important work. Its importance can be emphasised by a single example. What would the value to South Africa be if we could increase the butter fat per cent. of our Friesland cows from the average of, say, 3·4 per cent. to 4·4 per cent? Would the costs increase at the same rate?

We need improvement in our dairy cows. The cow which is heterozygous for desirable characters must be gradually eliminated until homozygosity is achieved. The beef breeds must be homozygous also for the "beef in the right places," and the correct rate of growth and deposition of fat. There is wide room here for future development of any improved strains or superior germ plasm that may be discovered.

And not only in our dairy animals. The same applies to our sheep, our pigs, our poultry. We are not yet at the goal with regard to any of these farm livestocks. These improved environments, with more fertile soils which I have visualised, will demand superior animals, better germ plasms, to make the fullest use of the conditions provided.

The future will hold a place of greater importance for the heavy horse than exists for it to-day. Remove the risk from horse-breeding in Natal, and horses second to none in South Africa will be produced on our improved pastures. They will liberate oxen from the yoke; this means better beef; they will

economise in grazing areas following intensive animals, i.e., dairy cows, suckling ewes, etc. They will leave behind them a rich residue not obtained behind tractors which require food not grown on the farm, whilst horse food is produced on the farm, and helps in the circulating of soil fertility.

When the correct sires have been found their fullest usefulness must be exploited by artificial insemination.

I am far from satisfied that we are getting the efficiency we ought to obtain from our draught animals. The methods of yoking remain crude in the extreme, and if we are to advance in the future there must be a betterment of the way we harness our animals to the various tillage implements.

The exact relationship of the tractor to the horse- or ox-drawn implements will have to be determined with some degree of detail. This is a very complicated matter, and one which ramifies through the complete crop production and soil fertility sides of our farming, and requires investigation by means of a practical farmer with a scientific training to assess its various ramifications.

Native Agriculture.

In considering the future of our farming the important part that the native and native agriculture play must not be lost sight of if we would keep a clear view of the future. The native peoples will not stand still. They will undoubtedly progress. As they progress wages will rise, either monetary wages or real wages. Since wages tend to rise faster than there is a general rise in the price level of primary products, the farmer who would earn the same money income for himself will have to adjust his systems and methods. It would appear that systems of farming involving less labour will have to be considered. This may be fewer units but more highly paid, as they will have to do more skilled work if the farmer will compete with the mines and industrial concerns. This progress of the natives will increase their wants. Everyone wants a bicycle now. Just how far these wants will cause them to seek work at a higher wage rate when their own economy has changed remains to be seen.

The Department of Native Affairs, through its Agricultural Department, is advancing the producing capacity of the natives at a rapid rate. By the methods demonstrated through the native demonstrators, viz., better seed, better espacement, more fertiliser, legumes and rotations the native is going to have a much larger food supply of his own production. He is going to be more independent. The greater wants and the greater food supplies will have to work it out as to what the native will do in the future.

These factors, rather vague at the present, will certainly influence the production of the European farmer in the future. He will be taking time by the forelock who studies these coming changes and develops systems of farming which call for a supply

of labour which he will be sure to get. No peak loads of labour but steady employment month by month.

Thus we see that farming has still a long way to go. I have referred very little to the marketing of farm products. These have come to be regulated largely through Boards under Government appointment. This whole marketing question is of itself a deep study, which has many ramifications, and which cannot be dealt upon in this paper, which I have tried to keep to the farm aspect as much as possible.

Agricultural Education.

To keep pace with the progress of science, to help in the advancement of our knowledge, to give that knowledge to our farmers demands a sound system of agricultural education. With the increased knowledge that we have to-day, to train the farmer in the various branches is a very important work. The farmer cannot find out all things for himself. Life is too short to spend it trying out new ideas as yet unproven. The farm does, however, remain a problem, one requiring constant observation in order to know the farm to the fullest degree.

Through our primary schools, where the first faint ideas are taught as nature study; through the special secondary schools, where the beginning of the practical application of agricultural scientific facts takes place; through the agricultural schools, where systems in farming in particular environments are taught and demonstrated, where the Why and How are answered and demonstrated, we pass to the next stage, the University College or University.

Here we are in a new country. There is no tradition behind our farming. No rule of thumb method handed down from generation to generation. Much knowledge has yet to be won. Many different environments have to be studied, and the soils, crops and livestock in these conditions fully investigated and the problems solved.

These research problems are very many and they are as equally varied, and there is an urgent demand that many of these problems shall not longer wait a solution.

To bring this solution nearer, there is required a band of young, willing, capable, industrious workers with a scientific bent built upon practical knowledge and experience. Our universities should be tackling these problems I have indicated. This heavy rainfall area east of the Berg has many problems and many possibilities, and the sooner its possibilities are realised and its problems solved the better, for the day approaches when the annual crop of wealth, won yearly by the farmer, will have to support the people of South Africa now dependent upon the gold mines. When that day arrives the whole phases of farming under divergent conditions should be near solution. There is, thus, needed here in Pietermaritzburg

a University Faculty of Agriculture, which can tackle some of the problems I have briefly mentioned. Their solution would be amply repaid many times over.

Is it too much to hope that there will soon be such a University Faculty of Agriculture established in Pietermaritzburg? Would it not be a really fine achievement in this year that the capital city of Natal celebrates its centenary?

Hence, and finally, our soils and climate remain more or less the same. Our knowledge of them must be advanced. Our crops and livestock will be improved and much variability and risk removed. Our scientific facts must be enormously added to and then built into sound systems of production organised to occupy fully a relatively low labour load. These facts and figures must be taught both to farmers and future teachers, and for this we require better educational facilities in the country and up to university status.

Knowledge is power, and as we add to our knowledge our power will increase. The future farmers are assured of interesting lives and happy occupations.

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SOME ADAPTIVE RESPONSES OF INSECT LIFE TO SEMI-ARID CONDITIONS IN SOUTH AFRICA

BY

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Presidential Address to Section D, delivered 6 July, 1938.

By having elected me as President, the Executive of Section D has done me a great honour, and my first duty is to convey to them my sincerest appreciation and thanks, and to express the hope that I may fulfil the demands of this office as conscientiously as my predecessors. It is with deep regret that I have also to record the loss that this section has incurred, during the past year, in the death of two of its Past Presidents—Professor H. B. Fantham and Professor J. E. Duerden, both of whom have been intimately associated with the activities of this Association, and more especially with Section D, during their stay in South Africa.

To a systematic entomologist whose duty in his special sphere is primarily to compile an insects' "Who's Who," the choice of a suitable subject for a presidential address is something of a problem, the solution of which becomes the more difficult when he peruses through the addresses of his eminent predecessors. In this address I have, however, attempted to solve this problem by presenting to you a few aspects of adaptation in insects as it appears to a collector who has spent quite a lot of time roaming about the Karoo, Namaqualand and South-West Africa, and who has thus had ample opportunity of becoming acquainted with the interesting forms of insect life in semi-arid and barren regions.

Southern Africa as a geographical region is, from an ecological point of view, one of the most interesting regions in the world, in that within an area of less than a million square miles practically every type of ecological environment is to be found. The traveller journeying from south to north will enjoy Mediterranean conditions at the one end and experience the vagaries of the Tropics at the other. In an east to west direction he will swelter in the moist heat of an almost Tropical coastal belt and terminate his journey in a desert. Between these four points of the compass he will find enough geographical and meteorological diversity to corroborate my statement that South Africa is one of the most interesting ecological regions. From a faunistic and botanical point of view, such a vast region, with

its diverse types of environments, will in the course of countless ages have elicited adaptive responses on the part of its indigenous fauna and flora. The evolutionary urge which, under Tropical conditions and in one direction expressed itself in the luxurious biocoenotic associations of a steaming mangrove swamp, gave rise in another direction and in a semi-arid clime to the forlorn Kokerboom and its frugal dependents. The particular type of environment which I intend to take in consideration is the semi-arid or barren type which, geographically, comprises the little Karoo, the Great Karoo, the North-Western Karoo, the western drought-stricken areas, Namaqualand, Bushmanland, the Kalahari and South-West Africa. As is evident from this list, these areas are by no means faunistically or geologically similar, but agree in that their general climatic and ecological conditions are more or less similar. Though the adaptive responses on the part of their insect fauna may be strikingly similar in regions far apart, it does not follow that their flora and fauna are generically or specifically always similar.

It is proposed to deal collectively with some of the adaptive responses in these regions where the average humidity is very low, where the rainfall is low, sporadic and capricious, where the temperature fluctuates between extremes but is relatively high during the day, and in summer, and where environmental conditions may be collectively summarised as being barren, semi-arid or even desert. In such regions we also meet with diverse physical and topographical features, such as great stretches of practically barren sand, dune sand or wind-blown sand, dry and sandy river courses, stretches of pebbly or gravelly desert, rocky or stony regions and barren hills, or even mountain ranges. The vegetation is usually sparse and varied, composed largely of plants or plant communities adapted to semi-arid conditions, such as the various kinds of Karoo plants, Xerophytes, Mesembryanthemums, Euphorbiaceae, milkbush, succulents, aloes, scattered thorn bush, growing chiefly along the dry river courses, and a transient flora springing up after favourable rains and collectively known as "opslag."

The insect fauna in these regions is remarkably rich, and contains numerous species which are peculiar to the sub-continent. Most of the orders are very well represented by very many species which are peculiar to semi-arid conditions in South Africa. In fact, the number of species which have become adapted to an existence in a semi-arid environment may be said to exceed those endemic in other environments in Southern Africa. Numerous species, however, show great adaptability in that they may be very widely distributed throughout the sub-continent.

The adaptive responses of insects to Karooid and semi-arid conditions may be considered under three separate heads. Firstly, we may consider adaptations which are primarily physiological, functional or metabolic, sometimes expressing themselves

externally and structurally in all kinds of modifications and specialisations in which the shape or structure of the body as a whole may be involved, in which certain parts of the body may be affected or in which certain structures or organs only may be modified or differentiated. Secondly, we may briefly refer to a few types of physiological or adaptive behaviour, and thirdly we may consider more specialised responses involving the reproductive activities, life histories and certain specialised stages in connection with reproduction.

Physiological and Structural Responses.

The chief climatic, meteorological and ecological factors in our semi-arid environments to which insects have become adapted are relatively high diurnal temperatures, excessive insolation, much radiant energy, low humidity or very low rainfall, long periods of drought, excessive evaporation, wind, special physical or topographical features in the environment and a comparatively sparse and often very specialised vegetal covering.

There is no doubt that temperature or heat, as a physical factor in an environment, plays a very important role physiologically in the life of an insect. The metabolism of insects in hot and dry environments is bound to be affected by temperature, which will elicit certain physiological responses. Our ignorance in regard to insect physiology is, however, so great that the little that is known about the few cases which have been subjected to experiment is not applicable to insects in general. We may, however, safely state that heat does influence the circulation, respiration and general metabolism of insects dwelling in semi-arid environments, resulting in physiological and structural responses. Physiologically, it has been demonstrated that high temperatures increase the rate of the oxidising processes and also increase the potential of reflex movements under various other stimuli. An increase of the oxidising processes may indirectly influence the nature and distribution of pigmentation. The most widely distributed pigment in insects is the brownish to blackish or black tints due to O-Dioxybenzol, melanin, and its derivatives. It is maintained that an increase in the rate of the oxidising processes, induced by high temperatures, may bring about melanin deposition. In our own barren regions as well as in the deserts in other parts of the world it is remarkable how many insects, especially *Coleoptera*, are black or dark in colour. This black colour-response is in itself something of a paradox, for according to physical science a black body absorbs radiant and heat energy and would thus facilitate the evaporation of body water. We must, however, remember that this black colour-response is also intimately correlated with the thickness and elasticity of the chitinous exoskeleton. In the case of beetles especially it has been demonstrated that the thicker and more elastic the chitin is, the higher the percentage of melanin and O-Dioxybenzol. As a fairly thick chitinous exoskeleton is also

a physiological necessity in order to prevent excessive evaporation, the rate of such evaporation will in all probability be less if the chitin is thick and with much black pigment than if it were thin and melanin-free. The fact that very many species of black Tenebrionids, and many Carabids and Cicindelids are also among the fastest runners there is also reason to believe that their locomotor energy and extreme activity, during the day at least, may be derived from their black colour which, apart from absorbing heat energy, also favours the absorption of the blue-violet or ultra-violet rays which stimulate metabolic activity. The much-debated and paradoxical black colour of the majority of beetles, inhabiting hot deserts, may thus prove to be a physiological response to the actinic rays in sunlight, the physiological effects of which are advantageously transformed into locomotor activity.

Notwithstanding the high percentage of dark or black-coloured insects in our barren regions, there are numerous whitish or pale-coloured, melanin-free forms which, though apparently mimicking the pale colours in their environments, nevertheless respond to heat and light in that they are able to reflect the heat rays which tend to raise their body temperatures. This whitish or pale coloration is nowhere better displayed than in certain Tenebrionid-beetles, such as *Calosis*, *Onymacris* and *Stenocara*, and in some species of Oedipodine locusts which inhabit the driest and hottest parts of Namaqualand, South-West Africa and the Namib. Apart from any locomotor energy that may have been indirectly derived from black pigmentation, the majority of insects and Arachnids which move about freely on the warm soil or sand in a barren environment display amazing locomotive powers, activities which are no doubt a physiological result of heat and light.

The influence of high diurnal temperatures on the bodies of insects, inhabiting dry environments, becomes more significant when considered in conjunction with other factors, such as light and radiation, humidity of the air, fluid content of the body, and the actual temperature of the insects. Several factors affecting the body temperature of insects are known, such as movements on the part of the insects, the humidity of the surrounding air and radiation. Several experimenters have discovered that movements of insects cause a rise in the body temperature. The insertion of a thermo-electric needle in the bodies of various insects, such as moths and bees, has proved that active movements may cause the temperature to rise to a variable extent, and in the case of bees this rise may be very high. In fact, it is even maintained that preliminary fluttering on the part of a flying insect is necessary to raise the body temperature slightly before the actual flight mechanism can come in operation. It has also been found that the body temperature of insects is lower than that of the surrounding air if the air is of normal humidity or dry, but higher than the air if the

latter is very damp. The actual body temperature is, however, a resultant of the effectiveness of two controlling factors, namely. the evaporation of water from the body which tends to lower the body temperature and the respiration which tends to increase it. Buxton, who compared the body temperature of a living and a dead Tenebrionid beetle exposed to the sun in the dry desert conditions of Palestine, found that the dead insect was hotter than the living one. He came to the conclusion that insects exposed to the sun and heat on the surface of a desert will absorb radiant heat at approximately the same rate as the desert, but that the lower temperature of a living insect under similar conditions is due to the loss of water, due to respiration. An increase of temperature in insects inhabiting barren regions may also be caused by direct solar radiation, and there is evidence to prove that the body temperature of diurnal insects does, in fact, rise shortly after sunrise, falling again after sunset, and there is no doubt that the direct sun-rays do also contribute to the activity of insects during the hottest part of the day.

High temperatures and a low humidity and the consequent high evaporation have called forth several adaptive responses on the part of insects. In order to prevent the excessive evaporation of water and body fluids, which are physiologically necessary for the maintenance of life, an adaptive response in the form of a very hard and almost impervious chitinous exoskeleton has been developed in numerous insects, especially in *Coleoptera*, such as the *Tenebrionidae*, *Curculionidae*. *Carabidae* and *Cicindelidae*, and in *Orthoptera*, such as the *Batrachotetriginae* and *Oedipodinae*. In the case of such *Coleoptera* which inhabit arid regions this exoskeleton has progressed so far that all the sclerites have become fused carapace-like. The elytra or upper wing-cases have become conjointly fused, and all the sutures and articulating parts of the body and legs have practically become obliterated. As examples of such beetles we may mention the numerous indigenous species of *Brachycerus* and *Psammodes*. The extreme chitinisation of these beetles and their remarkable tenacity in withstanding temperatures and dessication are suitable structural responses to semi-arid conditions.

In regard to structural responses to counteract the physiological effects of too much light and radiant energy we are entirely ignorant. The significance of such exoskeletal structures as a dense coat of pubescence, dense reflecting and resplendent hairs or opalescent scaling which adorn numerous Bombyliid-flies, Asilids and species of bees in semi-arid regions, is apart from teleological explanations still obscure. In this connection it is noteworthy to mention the beautiful gleaming white or silvery white pubescence which adorns so many different species of Bombyliid-flies and solitary bees in semi-arid regions. The ornamental value of such exoskeletal structures which usually excite man's aesthetic sense of colour and harmony is probably insignificant, and such structures are probably more of the nature

of structural responses which have been developed for the reflection of light and the prevention of heat absorption.

The phenomena of negative phototropism, in which insects avoid bright light, and negative thermotropism in which they avoid high temperatures or heat, may also be taken as physiological responses to the effects of light and heat. The reaction of many insects, more especially *Coleoptera*, to high mid-day temperatures in barren regions is a kind of geotropism in which they bury or hide themselves in sand or in the mould under bushes during the hottest part of the day. A very large number of desert insects have, however, solved the problem of escaping from high diurnal temperatures and bright sunlight by having become adapted to a nocturnal existence; such forms coming out only after dusk. In fact, during a windless day there is sometimes in barren regions or in deserts an uncanny silence, a peaceful calm which suggests the entire absence of life, but on the approach of evening and in the gathering darkness the wastes magically come to life again, and an almost unbelievable number of nocturnal species make their appearance.

Another factor in barren regions which no doubt plays an important role in the lives of insects, and which no doubt elicits physiological and structural responses, is wind. Winds are often very prevalent in open spaces, and their dessicating nature in semi-arid regions is very unfavourable to the indigenous vegetation and the insect life in such environments. Buxton, writing about the desert fauna of Palestine and Asia Minor, states that prevailing or periodic winds in such an environment may have brought about the apterous condition which is usually very prevalent in deserts.

Many South African locusts, belonging to the *Batrachotetriginae*, which are commonly known as toad-locusts and which are common on bare and open stretches of pebbly desert, have entirely lost their wings or these have become vestigial. In some of these forms the vestigial wings have become covered over by the enlarged thoracic shield and have assumed an entirely different function, namely, that of a stridulating organ for producing sounds. The rate of movements of air no doubt has an important bearing on the rate of evaporation, and in conjunction with high temperatures such movements no doubt influence the metabolism of insects adversely.

In connection with wind, it may be stated that during the period preceding a thunderstorm either the electric state of the atmosphere or other meteorological factors, such as pressure and humidity, elicit certain physiological or metabolic responses on the part of many of our indigenous insects. There appears to be a tendency for abnormal activity in the case of many species of beetles, flies, bees and wasps. Some species of beetles, not seen about during normal times, appear in great numbers even days before a storm, and others which normally hide under

stones or in crevices make their appearance. Some species of the remarkable and peculiarly flattened Tenebrionid-genus *Eurychora*, normally found under stones, actively move about outside before storms. The elytra and thorax of these beetles are adorned with a peculiar mould-like and waxy excrescence, which appears to be definitely hygroscopic and which probably enables these insects to sense the approach of cloudy weather. These beetles, as well as the males of certain species of fireflies, *Lampyris* and *Luciola*, are currently known as "reëngoggas" by the farming community, and are supposed to herald the coming of rain or a thunderstorm. The significance of the appearance of insects in large numbers, either before or after thunderstorms, is not known, but, as will be mentioned lower down, there is reason to believe that such appearances are sometimes connected with reproduction.

Special physical or topographical features in the same meteorological environment, with special ecoclimates and microclimates, have respectively elicited various physiological and structural responses on the part of insect communities which have become adapted to live in them. One special sphere of adaptation is the sandy environment, which has given rise to the arenicolous type of insect or larva. Very numerous species of insects inhabiting the sandy stretches of Bushmanland, the sandy coastal belt, the dune and wind-blown sand of the Kalahari and the Namib, and the more localised sand along dry river courses have become marvellously adapted to their sandy environment. In such insects the body has become structurally modified in many directions. The thoracic part usually overlaps the head, and the rest of the thorax and abdomen has assumed a compact ovoid or oval shape. The legs are usually almost abnormally long and spider-like or the front ones have become modified, and both the body and legs may be provided with stiffish, bristly hairs. The tarsi of the legs may be provided with a brush or comb of stiff bristles or hairs, and the tibial spurs and the claws may become elongated. Perhaps nowhere else in the world are there insects which have become so well adapted to a sandy environment as in the case of our numerous species of *Stenocara*, *Adesmia* and *Trachynotus*. These Tenebrionids all possess elongated and spider-like legs which are admirably adapted to cope with sand, and which enable these insects to run very rapidly over such a shifting medium. Many *Cicindelidae*, such as species of *Mantichora*, and Carabids, such as species of *Anthia*, have also developed elongated legs and similar running powers in the same type of environment. Other kinds of Tenebrionids, such as species of *Zophosis* and to a certain extent many species of the Carabid-genus *Graphipterus*, have developed an oval, hard and compact body, which is usually smooth or slippery, and which enables these insects to wriggle along over the sand with astounding rapidity even if their legs are short. The shape of the body is very similar to that of many aquatic beetles. This

general body shape or habitus, which is remarkably similar in beetles inhabiting a sandy environment and those adapted to water, may be advanced as an instance of parallelism in evolution where the same structural principle has been achieved, though the environmental media are entirely different. A similar parallelism is also evident in the case of the previously considered elongated legs. In the case of the aquatic Hemipteron *Ranatra* the legs have become elongated to facilitate its progress over the water. In the case of the Gryllacrid genus *Speleiacris*, inhabiting the caves on Table Mountain, the legs are also very much elongated, but in this case for the different purpose of crawling over the damp and mouldy walls of its environment. In the case of *Stenocara* and *Adesmia*, mentioned above, the elongated legs have been evolved to enable their owners to progress over shifting or loose sand. It thus appears that Nature has in many cases elicited a very similar structural response though the environmental medium in each case may be entirely different. Another structural adaptation to a sandy environment is the specialised type of front tibiae, which have become flattened and blade-like in the case of beetles, such as the Tenebrionid-genus *Gonopus*, and which are used for digging in the sand. The well-developed brush on the tarsal joints of fossorial wasps, such as Sphegids and Masarids, is another type of structural response which enables these insects to scoop out their nests in a sandy environment.

The rocky, shaly, gravelly or pebbly environment in barren regions, on the other hand, has elicited quite different responses, and one of the most remarkable adaptive measures in this case is what is called procryptic coloration and a superficial similarity to the pebbles, gravel, bits of rock and fragments of quartz in such an environment. In Southern Africa innumerable species of Oedipodine and Batrachotetrigine-locusts so closely resemble their stony, shaly or pebbly environment that they are difficult to see unless they move. The remarkable Batrachotetrigines are mostly apterous, and in the squat toad-like or pebble-like shape of their bodies they resemble pebbles even more closely. Not only is there a superficial resemblance to a bit of stone or a pebble, but the colour is also simulated. More remarkable still is the fact that individuals of the same species, dwelling in a certain area, will assume different colours in response to the different coloured pebbles or bits of shale in the various sites on which they occur. A dark brownish *Trachypetrella andersoni* or a species of *Batrachotetrix* will be found to occur among dark brownish pebbles, but another individual of the same species, occurring among whitish quartz pebbles, will assume a whitish or greyish white colour. In the case of the winged Oedipodines, a conspicuous transverse mark or band across dark wings is often whitish or greyish and even sometimes angular, suggesting an angular bit of quartz. This colour similarity to pebbles and the background in arid regions is not confined to insects, but even

Agama-lizards simulate the respective colours of their stony or rocky background. Even succulents, such as *Lithops* and *Conophytum*, have assumed the shapes and colours of the patches of pebbles and quartz pebbles where they occur. Not only is there a colour harmony between insects and their physical environment, but many Pamphagine-locusts, such as species of *Schinzia*, *Thrincotropis*, *Lamarkiana*, *Porthetis* and *Hoplolopha*, and also many species of Stick-insects and Mantids have become so remarkably adapted to the gnarled and drought-stricken plant environment that they simulate parts of such plants not only in colour but even in structure and texture. Is this structural and colour similarity of plants and animals in a semi-arid region solely due to a struggle for existence in which colour harmony is supposed to play a dominant role in a battle between aggressors and victims, or is this remarkable phenomenon to be physiologically explained as a sympathetic expression of living things in response to heat, light and radiant energy?

The rupicolous existence of desert insects is entirely different when the habitat is not among pebbles but under rocks, stones or within crevices. Practically any large-sized stone or rock in a barren environment has an association of different species, belonging to different orders, living under it or taking refuge under it. Probably there is no other type of environment in which an existence, either temporarily or permanently under loose rocks or stones, has been so lavishly exploited by various kinds of insects as in barren regions and deserts. An existence under a stone in a barren region affords many amenities which are absent outside. In this restricted environment or microclimate, such factors as temperature, humidity and absence of direct insolation all play a role, and many kinds of insects have physiologically and even structurally become adapted to live under stones. The most obvious structural response of Tenebrionids, such as *Eurychora*, *Steira*, *Lycanthropa* and *Geophanus*, and of the Hemipterous genera *Eupododus*, *Scantius*, *Brachyrhynchus* and *Neuroctenus* is an extreme dorso-ventral compression of the body. The bodies of such insects as *Steira* and *Neuroctenus* have become so much flattened that their owners are able to eke out an existence in the limited and restricted environment under a flattened stone. In correlation with such an existence physiological and metabolic activity is considerably reduced and such insects are usually extremely slow in their movements. Apart from specialised forms of insect life which have become adapted to live under stones and other kinds which only take refuge under them, the majority of ants in deserts also make their nests under stones and dwelling with them in simbiotic peace are usually all kinds of myrmecophilous insects. From an evolutionary point of view, myrmecophily in the desert probably had its origin in an independent existence of both partners, one of which, the less industrious and the non-ant one, eventually sacrificed its independence for a more profitable commensalism, and finally for a semi-parasitic existence.

The dependence of insects on plants, either directly or indirectly, in semi-arid regions has also resulted in an intimate biological connection in which the phytophagous kinds have become adapted to the indigenous plants physiologically or even structurally. The interdependence of plant and insect has in some cases developed so far that certain specialised plants are entirely dependent on certain specific insects for pollination. Unlike the vegetative luxuriance of temperate and tropical regions, the barren environment is economical, and specialises in certain directions with the result that a comparatively larger number of phytophagous and anthophilous insects is dependent on comparatively fewer flowering plants than is the case in a tropical or temperate environment. As the cyclic rhythm of reproduction in desert plants is to a large extent dependent upon climatic factors, such as suitable and adequate rains and favourable temperatures, the seasonal cycles of the insects, which are directly or indirectly dependent upon them, coincide with the maximum reproductive activity of such plants. As such vegetative activity is often very transient in a barren environment. the appearance of many kinds of insects is also transient. The imagal stages in their life histories appear when the flowers begin to bloom, and magically disappear when they wilt and fade. As rainfall and suitable climatic conditions are sporadic or capricious in barren regions, both plants and insects are similarly irregular in their seasonal rhythms and prolonged or unfavourable conditions may inhibit the physiological and reproductive activity of both plants and insects. Such vegetative activity may not necessarily occur at the same season, but often appears to a large extent to be dependent upon the rainfall whenever this happens during the summer. The appearance of certain specific kinds of insects, however, seems to coincide only with the appearance or reproductive activity of certain kinds of plants, but very numerous species seem to appear whenever there is a plant response, no matter what species of flowering plant. Incidentally, it is interesting to consider in this connection one aspect of the biological effect of human settlement in barren regions, and which is connected with the introduction and cultivation of flowering agricultural plants. Though never experimentally verified, there appears to be no doubt that sheep and goat farming in arid regions must play a very important role in disturbing the natural balance in nature and in causing the destruction of many indigenous Karoo plants on which stock feed. This destruction is not only brought about mechanically by overstocking and the consequent trampling, but also indirectly and biologically by grazing. Continual grazing prevents normal flowering, or brings about the destruction of buds and flowers, incidentally preventing seed production and also depriving anthophilous insects of their natural source of food. The normal and natural method of propagation of many valuable plants is thus suppressed by excessive grazing, a state of affairs which may lead to their disappearance, and also to that of the insects dependent upon them. At this juncture, however, a redeeming

feature comes in the form of a small plot or patch of flowering plants cultivated by the farmer. The biological fact that a very large number of species of anthophilous insects in barren regions is not specifically associated with any one species of plant is a factor in the preservation of such insects. By entirely artificial methods, namely, the cultivation of lucerne or other flowering plants, the farmer elicits a response on the part of the anthophilous insects in his region. Any collector of insects in the Karoo and Namaqualand is aware of the fact that in a patch of flowering lucerne, a sort of oasis in the desert, he is able to obtain, within a very restricted area, a very representative collection of Karoo insects.

Under natural conditions, an enthusiastic collector will, however, also find an amazing number of indigenous Karoo-insects on the numerous species of flowering Karoo plants after rains. It may be safely stated that during the maximum flowering period of plants in the Karoo and Namaqualand, representatives of practically all orders of insects appear in great abundance.

Specific adaptive responses are shown by those species of insects which are biocoenotically associated with certain specialised or specific plants. Plants, such as the tree-aloe or kokerboom, the numerous species of aloes, the Euphorbias, milkbush, leguminous plants and many other Karoo plants, have specific insects associated with them. The kokerboom, *Aloe dichotoma*, which is a haven of refuge to nesting birds and woodpeckers, also has associated with it Cercopid-bugs, species of *Sepullia*, which pass their entire life history at the bases of its leaves. Certain other kinds of *Hemiptera* feed upon its bitter juices, and cockroaches hide under the loose bark. In regions where the kokerboom population is being rapidly reduced through the commercial activities of aloe collectors, the diseased condition and the extermination of the remaining few are ascribed to the activities of the bugs on them, a condition of affairs which is to be attributed to the fact that now, within the limits of a special area, there is a bug-concentration, and the few stragglers or remaining ones are incapable of coping with the heavy demand made upon them by their natural phytophagous dependents.

As another instance we may take the Acacia-thorn tree. Perhaps no trees in barren environments have so many insects associated with them and, to a certain extent, adapted to them as the various species of *Acacia*. From an ecological point of view it would be a very interesting study for an ecologist to study in detail the biology, ecology, and life histories of the very numerous species of insects dependent upon a common species of this tree, such as *Acacia karoo*, where it thrives in barren regions. To enumerate only a few examples, there are the caterpillars of various kinds of moths, such as *Argenia mimosae*, *Coenobasis amoena*, *Acanthopsyche junodi* and *Gonimbrasia tyrrhea*, which feed on and destroy its leaves. Numerous species of *Hemiptera*, belonging to the *Coreidae*, *Lygaeidae* and *Pyrrhocoridae* pass

their entire life histories on the young shoots. Species of beetles, belonging to the *Tenebrionidae*, *Buprestidae*, *Curculionidae*, *Chrysomelidae* and *Cerambycidae*, are invariably found associated with it. Certain species of *Orthoptera* feed on its foliage, and cockroaches lurk under its bark. A peculiar genus of elongated ant, *Sima*, drills holes in the long thorns in the hollow interior of which it dwells and makes its nest, and species of *Camponotus*-ants imbibe the excretions from young shoots, and still other species of ants encourage the development of scale insects on its twigs. The puff-like yellow flowers are visited by innumerable species of bees, wasps, hornets and flies. Indirectly associated with it are the numerous kinds of carnivorous insects, which prey upon other insects or which are parasitic on the phytophagous species. Its bark and woody tissues are often riddled with the holes and tunnels of woodboring beetles and ants. Other kinds of plants, to which certain kinds of insects are partial, are the leguminous plants which are visited mainly by *Megachile* and *Xylocopa*-bees. Associated with the Asclepias, aloes and Euphorbias or milkbush are various kinds of *Hemiptera*, Chalcidoid-wasps, bees, and the larvae of many kinds of moths and butterflies. The locust *Phymateus*, numerous kinds of Lygaeid-*Hemiptera*, and the caterpillars of *Danaida* feed chiefly on the Asclepias growing along dry river courses. On a species of *Euphorbia* in the barren Knersvlakte, there is a unique Locustid, *Hemihetrodes bachmanni*, which is restricted to this region and has not been taken elsewhere. The very beautiful jewel beetles, belonging to the genus *Julodis*, which are, in a certain sense, peculiar to the Karoo, are invariably found associated or feeding on various Karoo shrubs and on species of *Lycium* or "Kriedoring." The numerous species of *Mesembryanthemum* are the chief source of food of innumerable species of beetles, locusts, bees, wasps and flies, and during the flowering season they teem with insect life.

Apart from insect association and certain plants, there are probably innumerable cases of biological interrelationships between certain kinds of flowers endemic in our barren regions and certain specific insects. Our ignorance in this respect is, however, profound, and an ecological study of Karoo plants and their attendant insects will no doubt reward the enthusiastic student with many surprises. A few known cases may be mentioned in this connection, in some of which even certain adaptive structures have been developed. A Nemestrinid-fly, *Prosoeca pictipennis*, has an abnormally long proboscis which exactly fits the corolla-tube of *Lapeyrousea fissifolia*, a member of the *Iridaceae* growing in Namaqualand. There is no doubt that this fly and this special plant are specifically and biologically interdependent; *Lapeyrousea* depending for its pollination upon this specific Nemestrinid. Other known cases of interrelationship are certain species of a Bombyliid-fly, *Apclysis*, which are invariably found in the corollas of species of *Mahernia*. Their association with these flowers has brought about a very great superficial

resemblance between the species. Associated with Stapelias are various kinds of sarcophagous and coprophagous flies which, no doubt, play a great role in their pollination.

The visitation of a large number of species, belonging to different families and even orders, to a comparatively restricted number of flowering plants has also brought about the evolution of similar types of colour patterns and superficial structural resemblances. Such superficial resemblances, but more especially that of form and shape, have always excited the fancy of collectors. Structural resemblances are displayed by quite a large number of our insects. We find, for instance, Mutillid-wasps, the females of which superficially resemble ants and even have the same habits. Many Bombyliid-flies bear a superficial resemblance to other kinds of *Diptera* visiting flowers, and many species of *Bombylius* even resemble Anthophorine-bees. Species of *Systropus* can scarcely be distinguished from *Hymenoptera*, such as *Sphex*, *Sceliphron* and *Belonogaster*. The carpenter bees, belonging to the genus *Xylocopa*, are mimicked by a peculiar genus of Robber-fly, and a large number of Syrphid-flies mimic wasps and hornets. There is no doubt that all these cases of procryptic coloration and structural resemblance will eventually be found to have a greater physiological significance in the economy of nature than a purely teleological one, based on anthropomorphic conceptions of protection and survival.

Certain Types of Physiological and Adaptive Behaviour.

Under this heading we may mention a few instances of adaptive responses which are displayed by some of our insects inhabiting barren regions, and which manifest themselves in certain types of behaviour or reflexes conditioned by certain stimuli in the environment. Among such reactions, the death-feigning instinct of a very large number of Curculionids and Tenebrionids is very remarkable. This phenomenon is especially well developed in the case of representatives of the Curculionid-genera *Episus*, *Microcerus* and *Brachycerus*. These insects, when disturbed either by the vibration caused by some approaching animal or person, or when touched, at once turn over on their sides or backs, stretching out their legs, becoming rigid and stiff, and assuming the general attitude of a dead insect. In this state, they may remain for a relatively long period. There is no doubt that this cataleptic state is a physiological condition induced by certain external stimuli. The true significance of this reaction is shrouded in obscurity, and several explanations have been advanced to account for it. It has been suggested that it is a kind of auto-hypnosis induced by nervous or physical shock. Another theory maintains that fear renders the blood toxic, and that these toxins affect the musculature and inhibit movements. In contrast to this self-induced hypnosis, there is another type of physiological and muscular reflex which may be termed the threatening response and which is displayed by various kinds of insects to certain

stimuli in the environment. This type of response usually takes the form of certain characteristic postures or attitudes in which the body and its appendages, such as the antennae, legs and sometimes also the wings, assume various threatening or intimidating attitudes accompanied by great excitability, tenseness and alertness. The large toad-locust, *Trachypetrella andersoni*, a typical representative of the toad-locusts, raises itself on its legs above the ground, stretching out its antennae rigidly and raising its short functionless wings. The hind legs are usually held a little apart so that the vivid and conspicuous violet-blue on their inner sides is exposed, and at the same time the insect may also stridulate by moving its hind legs up and down or to and fro. Among the Carabid and Cicindelid-beetles, the big black species of *Anthia* and *Mantichora* assume a similar attitude. In these beetles, trembling or shivering movements of the body also accompany the threatening posture. Many other kinds of insects, such as bugs, beetles, locusts and also fossorial and mason-wasps show this type of response. There is no doubt that in all these cases, vibrations on the ground or in the air in the immediate neighbourhood of such insects are the chief stimuli which elicit this type of behaviour. Another type of behaviour which is noticeable in a large number of insects, resting on shrubs or trees in open spaces, is what may be termed the dodging response. Such insects, especially the kinds of *Hemiptera* and *Coleoptera* which rest on the twigs, branches and stems of shrubs and trees, have the habit of taking up a position on the branch just opposite to the source of possible danger. A kind of hide and seek game is indulged in, the insect dodging and slipping round and round the branch, but always endeavouring to get the branch between it and the observer. This behaviour may be looked upon as a kind of response to escape in a special environment, and is probably elicited more by vibration than by vision.

The jumping instinct of locusts is another reaction which appears to be purely reflex. Both this reflex and those mentioned above are, however, not necessarily special reflexes of desert dwelling insects, but in a semi-arid environment the biological importance of such forms of behaviour may be different. In the case of the jumping reflex in locusts, it has been found that the ventral part or tip of the abdomen and also certain types of vibration act as stimuli for inducing the jumping response. It appears that when the abdomen of a creeping locust touches or rubs on the ground the jumping reflex is initiated. Similarly, the vibration caused by the flight of one locust over a resting one initiates the flight reaction in the resting individual. Another physiological reaction which appears to be more common among desert locusts and other *Orthoptera* is what is termed autotomy or the deliberate dislodgement of the hind legs. The significance of this reflex is not known, but there is no doubt that mechanical stimuli play a role in its production. The missing leg is eventually replaced by another leg which becomes larger every time the insect moults.

The most remarkable behaviour on the part of an insect is,

however, the tapping indulged in by very many species of "Toktokkies" (*Psammodes*). In these insects the males especially have the habit of tapping the ventral part of the abdomen rapidly on the ground, resting in between as if listening before the process is resumed again. Should there be another individual within range, he or she responds by similar taps. These insects are sometimes so responsive to tapping that a person, seeing a *Psammodes*-specimen, can elicit this tapping response by rapping or tapping on the ground with a stick or stone. There appears to be no doubt that this tapping is an instinct developed in order to inform the insect of the presence of another individual in its neighbourhood. There is the probability that a male is able to distinguish and to discriminate between the taps of another male and those produced by a female, and that by repeated taps on the part of both individuals the sexes are guided to each other during mating time. In this connection it is noteworthy to mention that immediately after a rainstorm in semi-arid regions a very large number of Carabid-beetles, Cicindelids, Tenebrionids, numerous species of ants and termites, various kinds of flying insects and a large number of Arachnids and Millipedes appear almost magically in great numbers, running about or apparently wandering about aimlessly. There is no doubt that this great abundance of life is not solely due to favourable meteorological factors prevailing at the time, or to the possibility of an adequate food supply, but also to some physiological stimulus in which the procreative urge plays a great role. It almost appears as if the favourable meteorological factors, heralding the recrudescence and rejuvenation of nature in the desert, are capable of stimulating the gonads and of inducing the physiological condition of a sex-urge in preparation for what is to come. We are, however, not in possession of available and reliable data concerning the true relationships between meteorological factors and the sex or copulatory instinct of insects. There is, however, no doubt that temperature does regulate the copulation of insects, and there is reason to believe that the favourable conditions prevailing just after rains in barren regions stimulate the copulatory instinct of a very large number of Arthropods. The apparently aimless wandering about of numerous species under such conditions tends to bring together individuals of opposite sexes.

Other physiological responses of a chemical nature are displayed by a variety of insects. One such response is the phenomenon which is characterised by the emission or evacuation of liquids or fluids in response to certain stimuli which, in the majority of cases, are mechanical or contact stimuli. This physiological reaction is commonly explained as a defensive adaptation, and is believed to have survival value in that enemies, on coming in contact with such insects, are warded off by the objectionable nature of the fluids. In the case of locusts, grasshoppers, very many kinds of beetles and many larval stages of insects, a dark brownish or blackish fluid is disgorged through the mouth, which is believed to be due to a reflex contraction of the stomach with

the consequent regurgitation of its contents. Most of the Carabid-beetles, belonging to the genus *Anthia*, are able to squirt out a fine jet or stream of fluid from the end of the abdomen, and in grasping a running *Anthia* one has to be very careful not to get this acrid and smarting fluid in the eyes. Other Carabids, such as our indigenous "Bombardier Beetles," *Brachinus* and *Crepidogaster*, emit a thick fog-like cloud of liquid or gas with explosive violence when they are touched or disturbed. In both the Anthias and the Bombardier-beetles, the fluids are secreted by specialised anal glands, and in the case of the Palaearctic Bombardier-beetles an analysis of the gas has revealed the presence of Oxygen, Nitrogen and Carbonic Acid Gas. There is no doubt that in the case of all these beetles, the emission of fluids and gasses is of defensive value, and that such evil smelling or obnoxious fluids do deter possible enemies.

Adaptive Responses in connection with the Life Histories and the Reproductive Activity of Insects in Arid Regions.

As the propagation and perpetuation of a species depend upon several vital and important functions, such as fertilisation, nest-building, egg laying, the rearing and care of larvae and protection for the pupae, these demands on the part of a species will have a special significance in barren regions. To ensure the continued existence of a species, the nests, eggs, larvae and the pupae must be suitably adapted to withstand the unfavourable conditions supervening in a semi-arid environment. Such adaptations may be of the nature of a direct physiological reaction to the environment, such as dormancy, or they may manifest themselves in special types of life history, in the construction of special homes or provision larders for the developing young by the adults, in specialised types of larval and pupal stages or in special precautionary measures taken by either the larvae or the pupae.

A common adaptive response of the various vital stages to unfavourable conditions is the physiological state of suspended metabolism. In this physiological state the metabolic activities in the eggs, larvae, pupae and even in the adults become suspended for more or less prolonged periods when adversely affected by unfavourable conditions. These periods of rest, technically known as diapause, are characterised by a reduction of activity in the motile stages. It appears that the diapause is merely a cessation of growth. During the cessation of this metabolic activity respiration is reduced, and the oxygen uptake very low. In a semi-arid environment such a state of dormancy is sometimes a sort of inborn rhythm. The physiological explanation of the diapause in the life histories of insects is still very uncertain. Some authors have maintained that it is a sort of autointoxication brought about by the accumulation of waste products, such as urates. Others believe it to be an hereditary rhythm, and some recent insect physiologists have advanced the view that it is maintained by hormones or internal secretions. One such hormone has already

been shown to be effective in inducing growth, and as the diapause is really a cessation of growth, the theory of effective internal secretions or enzymes may have some truth in it.

There is no doubt that in the case of very many desert insects either the egg-stage, the larvae or the pupal stages may undergo prolonged periods of dormancy. It has been found that the eggs of the " Brown Locust " can lie dormant for a very long period, as long as 3½ years. The larvae of Longicorn beetles and those of some other wood-boring beetles are known to be long lived, and a case is on record where the larva of a Longicorn-beetle lived for 24 years in the wood of a pencil box. The pebbly nests of species of *Osmia*-bees from the Karoo and Namaqualand can sometimes be kept for 2 or 3 years before the bees emerge. So little, however, is known about the life histories of our indigenous insects that it is impossible to make any reliable statement in regard to dormancy. Indirectly it is, however, evident that either the eggs or the pupal stages of very many species of insects in our dry and semi-arid regions must have this ability to lie dormant for long periods. This is evidenced by the fact that it is within the average experience of farmers and travellers in the Karoo, Bushmanland and South West Africa that regions which have been drought-stricken for years become magically transformed into a paradise, blooming with flowers and teeming with all kinds of insects after favourable rains. Even the adult stages are known to exist in a dormant or resting state, and digging in the mould under bushes or in the soil under stones during unfavourable periods or seasons often reveals the presence of the adults of various kinds of beetles, bugs and even of certain kinds of *Orthoptera* which are in a state of suspended animation.

As a special adaptive response to conditions prevailing in a dry or capricious environment, many kinds of insects become homodynamic in their life cycles, i.e., they develop successive generations as long as the conditions of temperature and humidity remain favourable. This is, no doubt, true of locusts, grasshoppers and numerous anthophilous species, such as bees, wasps and flies.

Most desert insects, however, have adopted specialised types of life histories in which their larval stages have become adapted to specialised diets. This is natural in an environment where the necessary food plants themselves are limited in species, specialised or few in numbers. The larval stages of phytophagous insects have thus become adapted to various modes of existence. As instances may be mentioned, the grubs of the very large number of indigenous species of the Curculionid-genus *Brachycerus* which have become adapted to feed on the bulbs of different kinds of bulbous plants occurring in the Karoo and Namaqualand, and in many cases certain species of *Brachycerus* feed only on certain types of bulbs. The larvae of species of certain Nitidulids, such as *Soronia*, tunnel in the leaves of Mesembryanthemums, and the grubs of species of *Julodis* tunnel in the stems and roots of a large number of Karoo plants. The dependence of larval stages on

certain specific plants is nowhere more evident than in the case of the numerous caterpillars of butterflies and moths of which there are quite a number of indigenous species in our arid regions.

A specialised phytophagous habit on the part of the larvae of certain Cecidomyid-flies and Chalcidoid-wasps has brought about a peculiar type of life history in which the developing larvae produce galls on certain plants. Various types of galls are thus developed on many kinds of Karoo plants. Such galls not only provide sufficient food for the larvae but also protect them from the unfavourable conditions prevailing outside the gall.

In this connection the nest-building activities of the adult insects may be conveniently considered. More than in any other environment it is necessary for insects in barren regions to provide adequate protection for the developmental stages. Nest-building has been exploited by several families of insects, such as the *Apidae*, *Vespidae*, *Eumenidae* and *Sphegidae*, the various members of which construct different types of nests. The nests usually consist of tiers or layers of cells in which the food material, in the form of pollen or bee-bread, is stored, and the eggs are laid. The carnivorous Sphegids usually stock their nests with paralysed caterpillars, insects or spiders. Various kinds of material are utilised in the construction of the nests. The most common material is usually mud, mud reinforced by grit or sand, woolly or cotton-like fibres obtained from plants, papery-like material derived from plants, resinous material obtained from plants and physiologically prepared by the insects, and resinous material reinforced by grit, sand or small pebbles. The hardness, durability and imperviousness of these nests in a semi-arid environment afford great protection to the developmental stages, while conditions outside remain unfavourable. The waxy or resinous amphora-like or pitcher-like nests of certain species of *Anthidium*-bees are very suitably adapted to arid conditions. The hard or pebbly nests of certain *Osmia*-bees which are usually exposed and attached to twigs can withstand any type of adverse condition, and the pupal stages within can lie dormant for years. In the case of many kinds of bees and wasps, the nests are not openly exposed but are constructed inside stems, dead and dried aloe stems, in the dead stumps of Cotyledons or in roots of various kinds of Karoo plants and even in the empty shells of snails. In this respect the various species of *Anthidium*-bees are of great interest in that they have exploited practically every type of niche in barren regions which will afford protection to their special nests. Any plant remains or dried stumps which will give a certain amount of security are utilised by this interesting bee-genus of which there are quite a number of species peculiar to our semi-arid regions. One species of *Anthidium* has actually adopted the method of storing bee-bread in the empty shells of the sand dune snail *Trigonephrus porphyrostoma*, which lie scattered about among the milkbush on the sand dunes of the coastal belt of Namaqualand. This peculiar adaptive response in regard to nest

building in an environment where even plant remains are exceedingly scarce, has also been adopted by a Eumenid-wasp inhabiting the very arid and sandy coastal belt of Luderitzbucht and the Namib. In this case the wasp utilises the empty shells of another land snail *Dorcasia rosacea*. A large number of Eumenid-wasps, however, attach their hard mud nests to the surfaces of stones, rocks and even to houses. Numerous species of nest-building Sphegid-wasps also use similar sites. The mud-nests in all these cases are usually hard and afford adequate protection to the developmental stages inside, protecting them against various kinds of unfavourable meteorological and climatic conditions.

The construction of nests or provision larders for the developing larvae underground or in sand is the usual method of *Psammocharidae*, *Masaridae*, many *Sphegidae* and even some kinds of beetles, and these insects are consequently very well represented in sandy environments where they may be seen scooping out holes in the sand. The nests are usually stocked with paralysed insects or spiders, or in some cases with bee-bread, and the sand, especially after rains, affords suitable conditions for the developmental stages, retaining a certain amount of moisture for quite long periods and at the same time maintaining a fairly constant temperature.

Adverse environmental conditions, which are more frequent in semi-arid regions, have necessitated specialised types of life histories, and it may safely be stated that a subterranean existence of both larvae and pupae plays a dominant role in the life histories of very many desert insects. So little, however, is known of the life histories of our Karoo insects that we are unable to express any opinion on the biology and ecology of the myriads of larvae living in the sand and soil or feeding on the roots of Karoo plants. Suffice to say that the larvae of very many Curculionids, Tenebrionids, Carabids, Scarabaeids and even of *Diptera* are invariably found in soil, either feeding on organic remains or on the roots and bulbs of plants. Soil or sand, even under unfavourable climatic conditions, affords a more suitable environment in that conditions of temperature and humidity are more satisfactory, and the larvae or grubs themselves are better protected against the harsh conditions above ground. The study of soil has revealed that its temperature at different depths depends on several factors such as the temperature of the air, the heat conductivity of the soil, its physical structure, its humidity and its composition. Larvae living in the soil or sand also have their own optimum and preferendum temperature and changes in soil temperature cause the migration of such larvae from one layer to another.

Specialisation in life histories has probably reached its climax in parasitism and hyperparasitism, and there is no doubt that in our semi-arid regions, this type of life history has been adopted to advantage by an exceedingly large number of insects. In fact two families, the Bombyliid-flies and the Mutillid-wasps, which

are entirely parasitic in their larval stages are extraordinarily rich in endemic species and genera. It may safely be stated that the *Bombyliidae* are more richly represented in our semi-arid regions than in any other environment in Africa. Parasitic bees are also well represented by several peculiar species of *Crocisa* and *Coelioxys*, and the parasitic *Chrysididae*, *Ichneumonidae* and *Braconidae* include many Karoo species. The small parasitic wasps, such as the numerous forms included in the *Chalcidoidea*, are either parasitic or hyperparasitic, and are also richly represented, though very little scientific work has been done on them in South Africa. The larval stages of all the insects mentioned above are usually parasitic on the developmental stages of other groups which are either more prolific or more industrious. The most heavily parasitised communities are usually the numerous species of Oedipodine and Batrachotetrigine locusts, various other species of locusts, the caterpillars of butterflies and moths, and the numerous species of industrious solitary bees and wasps which are all abundant during favourable conditions.

Parasitism, as an adaptive response to an insecure existence, is thus of great biological importance to desert insects. Closely allied to parasitism is the biological association of different kinds of insects which is known as commensalism or simbiosis. This association is, however, reciprocal in that value is given for value. The association of various kinds of insects with ants and termites, known as myrmecophily and termitophily respectively, is a case in point. In these cases the entire life history of the insect guest is often passed in the ant's or termite's nest, the ants feeding and attending to the larvae of their guests and in return obtaining from these certain excretions which they need or prize. In some cases, only the adult stage of the guest is able to supply the ant hosts with the excretions they need. Living with ants in the Karoo are various kinds of insects, some of them normally never found to be myrmecophilous in other environments. The beetle family *Tenebrionidae* is a case in point, and the genera *Argasidus*, *Smiliotus*, *Geophanus*, *Acestus* and *Adelostoma* are invariably found under stones in association with various kinds of ants. A large number of indigenous *Thysanura* or "Bristle Tails" are also found associated with the ant communities under stones in even the driest parts.

The role which the larva plays in the life histories of insects in dry environments has sometimes also necessitated special adaptive responses on the part of such larvae. The burden of obtaining nourishment has been transferred to a special type of larva which has become adapted to a peculiar mode of existence. In desert regions the specialised larval stage has been exploited by a variety of insects. Cases in point are the predaceous types of active larvae peculiar to Neuropterous insects, such as *Ascalaphidae*, and also to many Carabid-beetles, and also the nymphal stages of Reduviid-*Hemiptera*, which are usually found under stones, or which wander about under bushes in search of

food. Instances of more specialised types are the larval stages of the numerous species of *Myrmelionidae*, Neuropterous insects which have a superficial resemblance to Dragonflies. These larvae are peculiarly modified to live in dry sand or dust. A conical pit is constructed, at the bottom of which the larva lies hidden in the sand. The larva itself is a very peculiar creature, armed with formidable grooved and pincer-like jaws. In the pit-like trap it lies in wait for some unsuspecting victim which may accidentally tumble into this pit. The loose sand on the sides of the pit prevents the victim from climbing out before it is seized. Similar conical pits are also constructed by the larval stages of certain Leptid-flies, some of these larvae being capable of existing in this state for years. It is also significant that the larvae of all these pitdwellers can go without nourishment for long periods, a fact which has great significance in the regions where other insect life itself is not very abundant. These larvae leave everything to chance, and in a barren region this chance itself is only part of a greater gamble.

In the case of the sand-dwelling larvae of *Neuroptera* and *Diptera*, the instinctive behaviour to certain specific stimuli is very interesting. These larvae appear to be very sensitive to the vibrations caused by the kicking and struggling movements of other insects which happen to tumble into the pits. The least movement of the loose sand in the pit elicits violent snapping movements in the case of the Ant-lion or Myrmelionid, and lashing movements on the part of the Leptid-larvae. Some liquid poison or paralysing fluid is injected into the victim to prevent it from struggling or escaping, or even to prepare it chemically for subsequent digestion.

Equally interesting is the specialised larval stages of some Cicindelid-beetles, such as *Mantichora*. The elongated grub of these beetles makes a tunnel in the soil in which it lives. The grub itself is peculiarly adapted to live in its tunnel. The upper part of the head is in the form of a hard, chitinous, semicircular disc, apposed to which is a similar semicircular disc on the front part of the thorax. The two semicircular discs together constitute a button-like circular disc which exactly fits in the tunnel and is of the same diameter. This disc is kept at the level of the entrance to the tunnel. To maintain its position in the tunnel, the larva has developed a humped back which is provided with a brush of short spine-like hairs, and there are similar spine-like processes on the tail-end. By pressing the humped part against the wall of the tunnel and kicking with the tail end against the other, the grub is fairly secure. It is very sensitive to vibration, and can discriminate between vibrations made by its victims, such as insects, and also those produced by a grazing animal or a person walking. Its reaction to the latter is a very rapid withdrawal into the depths of the tunnel. The head is also provided with formidable pincer-like jaws by means of which the victim is seized. Any insect settling in the vicinity of the tunnel is at

once attacked and dragged in. It is also significant that the button-like discal shield is coloured yellowish and marked or spotted with brownish, superficially suggesting a small flower.

The larvae of numerous species of moths, especially the *Tineidae* and the *Psychidae*, in dry regions have adopted a novel method of protecting their bodies against enemies, insolation and high temperatures. Such caterpillars have constructed for themselves cases to live in, and which they drag about with them much in the same way as the caterpillars of the clothes moth do. In their case, however, the cases are made of tightly woven silk in which are incorporated fine grains of sand, grit, small fragments of quartz and even small pebbles. Others again utilise bits of stick, bark or even the thorns of plants. As cases in point we may mention the peculiarly flattened larval cases, composed of silk and an admixture of sand, constructed by the caterpillars of the Tineid-genus *Criticonoma* and the bags, composed of silk and dead leaves or sticks, constructed by the caterpillars of Psychids, such as *Acanthopsyche* and *Euneta*, and Tineids such as *Melasina*. These cases are invariably found suspended from the food plants, under bushes, under stones or attached to the surfaces of rocks. Such tough, hard and almost impervious cases afford protection to their owners and also to the ensuing pupal stages. The pupae in such cases can lie dormant for long periods, and the construction of such cases is a very efficient response in a barren region.

Specialisation of the pupal stage is also evident in some insects, especially in the Asilid and Bombyliid-flies. The pupae of these are provided with a number of cephalic spines and caudal spike-like spines and in contrast to the pupal stages of many other insects, they are capable of active movement. The pupae of those Bombyliids, of which the larvae are predaceous on the eggs of locusts, are capable of wriggling their way out through the sand, coming to rest near the surface where emergence of the adults is facilitated.

The pupal or resting stage in the life history of insects is usually well protected against unfavourable conditions, but in the case of insects found in barren regions, this pupal protection is usually even more evident. The pupa is either enclosed in a very resistant cocoon, or its own exoskeletal chitin is very tough and hard. The pupal cases of many moths are sometimes composed of a very tough, parchment-like membrane, reinforced by hairs of the caterpillar or by adventitious bits of foreign material or even grains of quartz or small pebbles. Such pupal cases are usually found attached under stones or in shady places. The cocoons of many Lasiocampid-moths are often very hard, horny or even calcareous, and are sometimes found attached to twigs, stems or the branches of their food plants. The soft-bodied pupae of many beetles are usually found deep down in the soil under shrubs and bushes, where the temperature and humidity are less variable and more constant, and where there is less chance of injury.

From these few considerations of some of the adaptive responses which I have endeavoured to outline, it is evident that there is a very large field of possible research in various directions affecting this problem of adaptation in semi-arid and drought-stricken regions. It is a research which, when conducted on an experimental basis, will throw much light on the problems of biology, ecology and evolution.

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ENIGE GESIGSPUNTE IN DIE SUID-AFRIKAANSE ARGEOLOGIE

DEUR

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Met Vier Teksfigure.

Voorsittersrede vir Seksie E, uitgespreek op 5 Julie, 1938.

Die Argeologiese wetenskap het in die laaste jare so baie vordering gemaak, elke tak van kennis omtrent die mens wat geleef het voor die koms van die Europeaan in Suid-Afrika het so gegroei, dat die moeilikheid om 'n toespraak te lewer op hierdie gebied nie geleë is nie in die keuse van 'n onderwerp, maar in die beperking daarvan tot redelike omvang. Dit was eers my voorneme om aan u die ontwikkeling te skets van ons insigte omtrent die werktuie van die Steentydperk, om dan vervolgens te behandel ons kennis van die outydse keramiek; dan sou ander gebruiksartiekels 'n beurt kry en ook die kunsprodukte wat die hele Suid-Afrika bedek; die geweldige uitbreiding van ons kennis omtrent die klipbouwerke, wat hulle uitstrek vanaf die Oranjerivier deur die Ooste tot in Noord-Afrika sou volg om tenslotte met u die mens wat dit alles nagelaat het, van antropologiese kant te bespreek. 'n Dergelike oorsig is egter veel te uitgebreid en ek het my genoodsaak gesien om my te beperk tot opmerkinge oor die werktuie van die steentydperk.

Die Werktuie van die Steentydperk.

Daar is sommige ondersoekers in Suid-Afrika, wat baie moeilikheid ondervind met terminologie en dit is derhalwe van belang om die betekenis van algemene terme so presies as moontlik vas te lê. Ek het sojuis die term ,, Steentydperk '' gebruik; hiermee bedoel ek 'n gedeelte van die tyd waarin die kwartêre afsettinge gevorm is en wel juis daardie tydsgedeelte waarin die afsettinge gevorm is wat klipwerktuie bevat. Dit is dus 'n benaming vir 'n tydsruimte, nie vir afsettinge en ook nie vir sekere argeologiese kenmerke nie.

Die Steentydperk word gewoonlik verdeel in twee afdelinge nl. die Ou-Steentydperk en die Nu-Steentydperk, ook wel paleolitikum en neolitikum genoem. Die Ou-Steentydperk word dan weer verdeel in drie kleiner afdelinge n.l. die Oudste Steentydperk, die Middelste Steentydperk en die Jongste Steentydperk. Al hierdie afdelinge is tydgedeeltes en kan nie aangewend word nie vir benaming van geologiese formasies of van argeologiese kulture. Dat die naam vir die tyd nie vir kulture gebruik kan

word nie, kan met 'n voorbeeld verduidelik word. In Europa het daar in die Ou-Steentydperk twee kulture gebloei, die Chelliese en die Acheuliese. In Oos-Afrika het Leaky werktuie gevind, wat na sy opvatting tot hierdie kulture behoort. Van Riet Lowe het in sy onlangse boek oor die Vaalrivier die Oos-Afrikaanse klipwerktuie bespreek in verband met die Suid-Afrikaanse en Europese (1, bl. 115) en hy beweer, dat die ontwikkeling van kulture in Europa eers 'n weinig agterbly en in Suid-Afrika eers baie agterbly by Oos-Afrika. Daarna loop Europa aan Oos-Afrika vooruit, maar Suid-Afrika bly ver agter Oos-Afrika. Om dit nou in ander woorde uit te druk: Op tyd 1 het al drie gebiede die kultuurhoogte A. Op tyd 2 het Oos-Afrika die kultuurhoogte B bereik; Europa kom net van A los en Suid-Afrika staan nog op A. Op tyd 3 bereik Oos-Afrika die kultuurhoogte C; Europa bereik dan B en Suid-Afrika staan nog op A. Op tyd 4 staan Oos-Afrika nog op kultuurhoogte C terwyl Europa dan C bereik en Suid-Afrika besig is om van A weg te kom. Op tyd 5 staan Europa op D, terwyl Oos-Afrika besig is om van C weg te kom en Suid-Afrika B bereik. Op tyd 6 bereik Europa E, Oos-Afrika D en Suid-Afrika gaan na C. Volgens hierdie opvatting moet die kultuur D, wat Europa in tyd 5 bereik iets anders wees as die kultuur D wat Oos-Afrika in tyd 6 bereik. Dit wil sê dat b.v. die Europese Aurignacsiese kultuur afwyk van die Oos-Afrikaanse Aurignacsiese kultuur. Die tydfaktor is natuurlik nie die enigste faktor nie, maar dit is duidelik dat hy saamtel. Dit is dus reg om ooreenkomstige kulture met verskillende name aan te dui in verskillende wêreldstreke. Neem nou b.v. die geval van tyd 3. Toe was die kultuur van Oos-Afrika C, van Europa B en van Suid-Afrika A. Stel nou dat ons in Europa die kultuur van daardie tyd nie B sou genoem het nie, maar aan die kultuur die naam sou gegee het van die tyd, n.l. 3. Die ooreenkomstige B kultuur in Oos-Afrika sou dan ook die 3 kultuur genoem word, maar dit kom voor in tyd 2 en die benaming is 'n onwaarheid. Die ooreenkomstige 3 kultuur in Suid-Afrika kom voor in tyd 5. Dit is duidelik dat so 'n soort van benaming dwaas is, omdat dit die tyde deurmekaar gooi. Dit is egter 'n metode wat in die laaste jare in Suid-Afrika konstant gevolg word. So gebruik prof. van Riet Lowe nog in sy reeds genoemde publikasie deurlopend die benaming " Middle Stone Age " vir 'n geselskap werktuie wat deur my lank gelede reeds met die benaming Mosselbaaise Kultuur voorsien is. Selfs in 'n tabel op bl. 72 noem hy van onder na bo vier Stellenbosch-Industrieë, dan twee Fauresmith-Industrieë, dan die " Middle Stone Age " om te eindig met die Smithfieldse en Wiltonse Industrie. Hier word tussen industriebenaminge 'n Europese tydsbenaming gebruik vir 'n Suid-Afrikaanse Kultuur, wat volgens die voorgaande foutief is, nie alleen omdat die naam van 'n tyd nie aan 'n kultuur gegee kan word nie, maar ook omdat volgens van Riet Lowe se eie betoog soos hiervoor verduidelik, die ,, Middelste Steentydperk " van

Suid-Afrika glad nie ooreenkom nie met die Middelste Steentydperk van Europa.

Sojuis is die term "Kultuur" gebruik. Wat word daar in die Argeologie onder verstaan? Kultuur is die veredeling wat die klippe ondergaan het deurdat die mens daaraan gewerk het. Dit is 'n woord wat 'n algemene betekenis het. Nou blyk dit egter, dat die veredeling nie altyd van dieselfde aard is nie. Daar is heelwat verandering in die veredeling, maar met dié eienaardigheid, dat dieselfde verandering telkens weer op nuwe vindplekke in ontelbare individue teruggevind word. Om nou die verskillende groot stadia van mekaar te onderskei word name aan hulle gegee, waarvan die woord kultuur 'n deel vorm, terwyl die ander deel b.v. gelewer kan word deur die naam van die plek waar die verandering die eerste opgemerk is, of waar die bepaalde tipe van veredeling baie voorkom, of waarvan dit die eerste maal beskryf is. So praat ons van Stellenbosche, Vaalse, Pnielse, Mosselbaaise en Koningse kultuur, omdat die verandering in die veredeling of in die bewerking en vorming van die werktuie vir die eerste maal op die genoemde plekke gekonstateer is.

Die verandering in die vorming van werktuie het geen reëlmatige verloop nie. Dit kan gebeur, dat 'n werktuigtipe in sy beginstadium ru en onbeholpe gemaak is, dat hy in sy ontwikkeling 'n kulminasiehoogte bereik, waarin hy 'n toonbeeld van skoonheid en doelmatigheid is, om daarna weer agteruit te gaan en te verdwyn. 'n Dergelike werktuigtipe kan as kenmerkende bestanddeel van 'n kultuur gekies word, d.w.s. dat alle homogene werktuiggeselskappe waarin so 'n werktuigtipe voorkom, tot een en dieselfde kultuur gereken word. Dit het in Suid-Afrika gebeur met die Stellenbosche kultuur in sy mees uitgebreide betekenis. Onlangs is hierdie Kultuur verdeel in ses afdelinge en elk van hierdie afdelinge is gekenmerk deur die aanwesigheid van 'n bepaalde tipe van handpik; die eerste afdeling het die handpik in sy beginstadium, die laaste in sy endstadium; na die laaste afdeling kom die handpik nie meer voor nie.

Daar is egter nog ander eienskappe wat as kenmerk vir 'n Kultuur gekies kan word, b.v. die wyse waarop werktuie gemaak is. Die tegniek wat toegepas is om werktuie te vorm sal in die loop van tyd verander, waarskynlik verbeter, miskien selfs plotseling vervang word deur 'n metode, wat voorheen nie bekend was nie. Dit kan gebeur, dat daar in een tyd meer as een tegniek bekend is, en dat die een tegniek bo die ander domineer. Dit was blykbaar die geval gedurende die gehele paleolitiese tyd. Heel waarskynlik was in die begin die handpik die enigste werktuig, altans vir 'n deel van die bevolking; die werktuig is dan alleen gemaak van 'n rolsteen waar stukke afgeslaan is om die verlangde vorm te kry; of die skilfers wat ontstaan het, gebruik is, weet ons nie. Eers baie later word op eenmaal werktuie gevind, van volmaakte skoonheid en tegniek, sowel byle as handpikke, wat op eenvoudige wyse gemaak is van 'n *skilfer*. Op dieselfde tyd egter word daar *nog* handpikke gemaak van *kerne*. Die skilferbyle

en- handpikke is gevorm deur 'n skilfer af te slaan van 'n klip, waarop vooraf 'n slagplatform voorberei is. Van die skilfer is daarna die rand teenoor die slagknoffel afgeslaan sodat 'n klip met 'n parallelogramvormige deursnit daaruit ontstaan het. Een end is daarna afgestomp en die ander end is òf so gelaat om 'n bylvorm te behou òf is toegepunt om 'n handpik te maak. D.w.s. met 'n paar houe is hier 'n fraaie werktuig ontstaan, wat vir dieselfde doel kan dien as die mooi handpik, wat van 'n kern gemaak is. Waar sulke merkwaardige veranderinge in die werktuigvorming optree kan hulle gebruik word as kenmerk van 'n kultuur. Dit is deur my gedoen in 1926 toe die geniale skilferbyle en enige ander werktuie gekies is as verteenwoordigers van die Pnielse Kultuur (2). Hier is iets totaal afwykend van die kerntegniek en dit is geen wonder dat die tegniek van die Pnielse byl by sy ontdekking 'n geniale gedagte genoem is, want werk op skilfers was voor 1926 nie van ouere kulture in Suid-Afrika bekend nie.

Dit is dus om besondere tegniese redene, dat die Pnielse Kultuur afgesonder is van die ander Paleolitiese kulture.. Die oorblywende materiaal is egter ook nie, van tegniese standpunt gesien, 'n eenheid nie. Die oudste handpikke is gemaak op ruwe wyse. Van 'n rolklip is om die ander links en regs skilfers afgeslaan, sodanig dat 'n puntvormige werktuig met ruwe rand ontstaan het. Die toegepaste tegniek is deur Goodwin die Abbeville Tegniek genoem (3). Daarna is werktuie op 'n minder ruwe wyse gemaak. Die werktuie vertoon lang plat skilfervlakke wat loop van 'n rand wat nie meer sig-sag-vormig is nie en wat die werktuig dunner maak as voorheen. Breuil meen, dat hierdie werktuie nie afgeskilfer is met kliphamers nie, maar met houthamers (4). Hier sou dus 'n verandering wees in tegniek wat tot resultaat gehad het 'n meer verfynde werktuig en dus 'n hoëre kultuur. Werktuie van hierdie hoëre kultuur is ook in Suid-Afrika gevind, en is deur my reeds in 1926 beskryf as verteenwoordigers van die Vaalse Kultuur (2). Die handpikke wat die Abbevillese tegniek vertoon is deur my as karakteristies opgevat van die Stellenbosche Kultuur en dit is derhalwe 'n heel ander kultuur as die " Stellenbosche Kultuur " met ses afdelings wat onlangs voorgestel is. Hierdie groot " Stellenbosche Kultuur " is 'n suiwer tipologiese kultuur op beperkte grondslag (alleen vorm), gekenmerk deur die " type-fossil, the bifaced coup-de-poing or hand axe " (1, bl. 110). Die Stellenbosche Kultuur soos deur my opgevat, die Vaalse Kultuur en die Pnielse Kultuur is kulture wat gekenmerk word deur 'n bepaalde tegniek. Die tegniek wat toegepas is om 'n werktuig te maak is van groter betekenis vir die beoordeling van die kultuurhoogte van 'n tyd as die vorm van die werktuig, omdat die tegniek kan toegepas word op 'n hele geselskap werktuie, terwyl die werktuig self miskien 'n oorblyfsel is uit 'n verlede tyd. In hierdie opvatting staan ek nie alleen nie. Van Riet Lowe in sy onlangse bespreking van Leakey se indeling in Oos-Afrika (1, bl. 124), haal die volgende woorde aan van

Leakey: "The first stage of the Acheulean is also marked by the appearance for the first time (as far as the evidence at present available goes) of a type of implement which has not yet occurred before but which is a more or less common and typical tool in all the stages of the Acheulean. This implement is the cleaver." Hierop gee van Riet Lowe die volgende kommentaar: "I mention this because I do not think the cleaver is a significant factor. Technique alone is sufficiently important. Cleavers do occur in the African Chellean in the South and further work may reveal their occurrence in the North." Sover van Riet Lowe. Omdat alleen die tegniek van voldoende betekenis is het ek in die Suid-Afrikaanse Oudste Steentydperk drie kulture herken, die Stellenbosche, Die Vaalse en die Pnielse en terwyl van Riet Lowe nie dink, dat die voorkome van die byl in Oos-Afrika 'n belangrike faktor is nie, dink ek nie dat die voorkome van die handpik in Suid-Afrika van voldoende betekenis is om 'n kultuur te kenmerk nie. Dit loop net soos van Riet Lowe in Oos-Afrika van die byl verwag, deur meerdere kulture heen en is dus nie kenmerkend nie.

Die Mosselbaaise Kultuur word ook gekenmerk deur 'n bepaalde tegniek. Baie werktuie is gemaak van lang skilfers wat sekundêr bewerk is langs die rande aan een oppervlakkant van die werktuig, òf gedeeltelik ook aan die anderkant, òf geheel aan albei kante.

Ook die Koningse Kultuur word daardeur gekenmerk dat die meeste werktuie gemaak is van skilfers. Die sekundêre bewerking van die rande is meestal steil, sodat 'n taamlik stomprandige werktuig ontstaan. Toe hierdie kultuur vir die eerste maal in 1926 deur my beskrywe is (2), kon slegs twee afdelinge daarin aangetoon word. Die onderste gedeelte het ek geen naam gegee nie, en die toe reeds bekende Smithfieldse Industrie het ek as die boonste gedeelte opgevat. Maar reeds in 1928 (5) het geblyk, dat daar nog 'n derde industrie was, wat na die Smithfieldse Industrie gekom het. Behalwe hierdie fout het ek in 1926 nog die "Victoria West-Kultuur" by die Koningse Kultuur aangesluit en die Mosselbaaise Kultuur beskou as jonger as die Koningse Kultuur. Vandag weet ons dat hierdie opvattinge verkeerd was. Dit is nou maklik om foute aan te wys in die indeling wat ek in 1926 opgestel het, maar dit moet nie vergeet word nie, dat dit die eerste indeling was, wat geprobeer het om ons werktuie te rangskik na ouderdom. Peringuey en sy navolgers het nie verder gekom nie as 'n verdeling in twee groepe, ooreenkomende met die Oudste en Jongste Steentydperk. Selfs die herhaaldelik in die literatuur genoemde sogenaamde konferensie van argeoloë in 1926 het vier dae nadat my artikel voorgelees was nog op Peringuey se standpunt gestaan, met die besonderheid, dat elke groep nog drie horisontale gedeeltes gehad het. Daar was dus niks om op te steun nie, behalwe vergelyking met die Europese literatuur. Daar is vandag geen twyfel nie, dat die Koningse Kultuur jonger is as die Mosselbaaise Kultuur (6). Ook het geblyk dat die jongste gedeelte van die Koningse Kultuur, wat

ek Poortse Industrie genoem het, dieselfde is as wat deur ander Wiltonse Kultuur genoem word. Daarom word die laaste gedeelte van die Koningse Kultuur Wiltonse Industrie genoem.

Wat word in die argeologie verstaan onder die benaming industrie? 'n Industrie is in alle geval van geringere omvang as 'n kultuur, want ons spreek van die staalindustrie, skeepsbou-industrie en ander industrieë van 'n volk; hulle maak dus deel uit van sy kultuur. Daarom is die benaming industrie toegepas op sodanige algemene veranderinge in die tegniek van 'n kultuur waardeur 'n hele geselskap van werktuie kan onderskei word van ouere of jongere gedeeltes van dieselfde kultuur. 'n Goeie voorbeeld van sulke industrieë bied die Koningse Kultuur.

Die Koningse Kultuur omvat drie industrieë, n.l. die Koningse Industrie, die Smithfieldse Industrie en die Wiltonse Industrie. Die werktuie van die Koningse Industrie is betreklik groot. Slagmesse is volop en soms so breed as die lengte van 'n hand; endskrapers (eendebekskrapers) is weinig talryk en dikwels so lank as 'n vinger, skyfskrapers so groot as 'n koffieblikdeksel of groter; kampunte is soms ook buitengewoon groot. Die ovale, opsetlik gemaakte afwerker is groot. Die werktuie van die Smithfieldse Industrie is kleiner. Slagmesse is seldsaam en smaller as 'n vingerlengte; endskrapers, hier eendebekskrapers genoem, kom in oorweldigende aantalle voor; hulle is buitengewoon lank as hulle twee-derde van 'n vingerlengte haal, gewoonlik het hulle die lengte van 'n vingerlid; skyfskrapers is ook seldsaam en 'n bietjie groter as 'n halfkroon; kampunte het ek nie in die Smithfieldse Industrie aangetref nie; die ovale afwerker is klein en baie seldsaam. Die werktuie van die Wiltonse Industrie is weer baie kleiner as die van die Smithfieldse Industrie. Slagmesse is nie hierin aangetref nie; endskrapers, hier duimnaelskrapers genoem, is talryk en het gewoonlik die grootte van die duimnael, maar hulle word kleiner as 'n kind se pinknaeltjie; skyfskrapers is baie seldsaam en so groot soos 'n sjieling; die ovale afwerker het verdwyn. Nuwe werktuie tree op. Die lemoenskyfskraper is alleen bekend uit die Wiltonse Industrie; pylpunte uit die Wiltonse en Smithfieldse Industrieë en miskien ook uit die Koningse Industrie. Hier is alleen 'n aantal van die vernaamste werktuie van elke industrie genoem, om 'n volledige oorsig te gee van al die werktuie sou ons te ver voer.

Die tegniek van die drie industrieë het blykbaar met die loop van tyd ook 'n veredeling ondergaan, want werktuie van die Smithfieldse Industrie is sonder twyfel fyner of voorsigter bewerk as die van die Koningse Industrie. Werktuie van die Koningse Kultuur toon duidelik, dat twee tegnieksoorte gebruik is, n.l. 'n slagtegniek en 'n druktegniek. Die bewerking van die pylpunt toon toepassing van 'n druktegniek. Die werktuie van die Koningse Industrie is almal gemaak met 'n slagtegniek.

Klipwerktuie lê nie reëlmatig versprei oor die land nie. Hulle word in groot aantal gekry in rivierbeddings, in ou gruisafsettinge van riviere, op rivierwalle en dan soms naby of soms ver van

die rivier of spruit, naby ou fonteine, in grotte en op nog baie ander plekke. Enkele werktuie kom oorals verspreid voor. Dit is veral die vindplekke op of naby rivierwalle, wat nóg iets opvallends toon. Die werktuie lê dan nie reëlmatig langs die rivier se loop versprei nie. Dikwels word op 'n plek by die rivier, wat ver uitsig bied oor sy loop of wat om ander rede gunstig is, talryke werktuie gevind van die Koningse Kultuur. Behalwe werktuie van 'n enkele of miskien al drie Industrieë, lê daar ook groot hoeveelhede skilfers. Dit lê voor die hand om sulke plekke op te vat as werkplekke. Hier is die werktuie gemaak, die oorblyfsels van die fabriek lê oorals rond. Dit is ook moontlik dat die makers van die werktuie op sulke plekke gewoon het Dit blyk baie gou dat werktuie van een industrie op baie werkplekke gevind word; en natuurlik nie net in een riviersisteem nie; ook in die aangrensende sisteem en ook in die volgende. Kortom, die mense wat werktuie van 'n bepaalde industrie gemaak het, het 'n groot gedeelte van die land bewoon en waar hulle ookal mag gekom het, daar het hulle hul werktuie gemaak. Natuurlik het die mense in groepies oor die land gewoon. Dit is ook 'n feit, dat daar geen twee groepe mense is, wat presies eenders is nie; derhalwe sal die gereedskappe wat een groep maak en gebruik ook wel iets afwyk van die van 'n ander groep. Behalwe hierdie menslike faktor is daar egter nog ander faktore wat verskille veroorsaak in dieselfde industrie in verskillende dele van die land. Die vernaamste hiervan is wel die aard van die gesteente.

Die volk wat in die Oranje Vrystaat sy werktuie gemaak het van Lidianiet, het in die meeste gevalle 'n baie fyne, homogene gesteente gehad, sonder splytvlakke en barsies en van besondere taaiheid. Hiervan kan met bekwame hande buitengewoon fraai werktuie gemaak word. Die eienskappe van lidianiet is egter nie konstant nie. Dit was oorspronklik 'n lei- of 'n kleigesteente wat 'n metamorfose ondergaan het in die kontaksone van b.v. diabaasgange. Hoe nader die kleigesteente by die diabaasgang was, hoe meer is hy verander. Hoe nader die lidianiet by die ganggesteente is hoe harder en taaier is hy, hoe verder van die gang hoe brosser; ver van die ganggesteente gaan hy oor in die oorspronklike kleisteen. Daar is streke waar die lidianiet nie fyn is en ook nie homogeen nie. Hier was dit vir die mens eenvoudig onmoontlik om net sulke mooi werktuie te maak as van die ideale lidianiet. Daar is egter ook streke waar geen lidianiet voorkom nie of uiters seldsaam is. Hier is ander materiaal gebruik en natuurlik nie noodwendig met dieselfde goeie gevolg nie. Ek het b.v. eendebeskrapers gesien van growwe kwartsiet, lelike lomp en ruwe werktuie, maar eendebekskrapers en dus behorende tot die Smithfieldse Industrie. Uit dit alles volg, dat die werkplekke van 'n industrie "individuele" verskille sal vertoon. In die meeste gevalle sal die verskille weinig of glad nie opval nie, maar feitelik is elke werkplek verskillend van die ander. Nou is dit natuurlik moontlik om aan hierdie verskille name te gee, maar dan sou feitelik elke werkplek 'n

ander naam moet kry en dit is nie van die geringste betekenis nie om so 'n nadruk te lê op " individuele " verskille. 'n Dergelike metode is egter gevolg met die Mosselbaaise Kultuur, waarvan 'n groot aantal sogenaamde " variasies " oor die hele land bekend gemaak is. Dit is moontlik, dat miskien een van hierdie " variasies " 'n ontwikkelingsstadium van die kultuur voorstel wat verskil van die stadium waarin die werktuie van Mazelspoort verkeer; dan sou daarmee miskien 'n industrie van die kultuur bekend gemaak wees. Die meeste van die " variasies " egter is net name vir ander werkplekke. Ek wil hier van die geleentheid gebruik maak om die vindplek naby Mazelspoort die tipiese vindplek van die Mosselbaaise Kultuur te noem. Die kultuur het sy naam gekry na die vindplek, waar die werktuie vandaan kom, wat aanleiding was tot afskeiding van hierdie kultuur. Maar die eerste volledige versameling werktuie van hierdie kultuur is beskrywe van die vindplek naby Mazelspoort (6); boondien is dit alleen Mosselbaaise werktuie wat op die vindplek gekry is en geen ander nie. Dit verdien dus as tipe-vindplek van die kultuur beskou te word.

Aan die einde van die bespreking van die terminologie wat op die verskillende kultuurfase toegepas word, moet ons 'n oomblik stilstaan by die nuwe gedagtes wat in die laaste tyd in Europa ontstaan het met betrekking tot verskille wat oor verskillende streke binne kulture aangetref word. Abbé Breuil het reeds in 1932 sy opvattinge hieroor uiteengesit (4) en Burkitt het sojuis 'n kort en baie heldere oorsig oor die moeilikhede gegee (7). Daar is in die Ou-steentydperk in Europa 'n kerntegniek gevind, waarop b.v. die Chelliese en Acheuliese Kulture gevestig is. Daarnaas bestaan 'n skiltertegniek waarop b.v. die Clactoniese en Levalloisiese Kulture gebaseer is. Die kulture van die kern- en van die skilfertegniek kom byna oorals in Wes-Europa so gemeng voor, dat hulle eers sinds kort gelede van mekaar kon geskei word, omdat werk in ander dele van die wereld gewys het op verskillende oorsprong. Van Duitsland tot Sjiena sou hoofsaaklik skilfertegniek geheers het, terwyl volgens Burkitt op dieselfde tyd in Afrika die volke wat die kerntegniek toegepas het, oppermagtig was. Hierdie toestand word toegeskrywe aan die bestaan van twee beskawinge naas mekaar. Die een beskawing sou dan gebruik gemaak het van die kerntegniek, terwyl die ander beskawing die skilfertegniek toegepas het. In Wes-Europa het die produkte van die twee beskawinge gemeng.

Van Riet Lowe het met die grootste beslistheid die moontlikheid van die bestaan van twee sulke beskawinge langs mekaar in Suid-Afrika verwerp. In sy onlangse werk (1) sê hy op bl. 100: " The hand-axe (Abbeville) and flake (Clacton) techniques are inseparable, together they combined to serve the purposes of the makers of Stellenbosch I tools." " The modern European school of thought indicates a parallel evolution of the Chelles-Acheul sequence on one side and the Clacton-Levallois on the other. I do not see that here. In the Vaal River basin these two techniques

—primarily hand-axe or "core" and "flake"—are part and parcel of the same industry." En op bl. 104: "With the passage of time and the greater use of indurated shale he became more expert, Stellenbosch IV developed and ultimately the Fauresmith with its greater number of Micoque and Combe Capelle type hand-axes and more advanced Levallois technique to which he now added blades—the hand-axe, flake and blade techniques being intimately associated in this culture." En op bl. 124: "Once it is universally recognised that the known tools of the hand-axe culture of the Uganda, Tanganyika and Kenya Chellean and Acheulean and the South-African Stellenbosch were made on flakes as commonly as on cores and that these flakes and core tools were an integral part of the same culture . . . ."

Dit is genoeg om aan te toon met watter beslistheid aan ons voorgehou word, dat daar in Suid-Afrika geen sprake kan wees nie van twee beskawinge in die Ou-Steentydperk en dat dit totaal onmoontlik is om kerntegniek en skilfertegniek hier van mekaar te skei.

Laat my nou eers daarop wys, dat die nuwe gedagtes in Europa gebaseer is op feite. Die besliste afwysing vir Suid-Afrika bestaan alleen uit blote beweringe, of miskien gevoelsuitinge. Geen enkele feit word aangehaal nie om hulle te staaf, behalwe miskien as hierbo bedoel word, dat in die Vaalrivier die twee tegnieke deurmekaar voorkom.

Dat die tegnieke in Wes-Europa so gemeng is word daardeur verklaar, dat die streek 'n doodloopstreek was vir kultuurstrome wat van die Ooste en Suide ingekom het. Maar Suid-Afrika is tog nie minder 'n doodloopstreek nie vir kulture wat van die noorde ingedring het? Die draers van die twee beskawinge sou mekaar hier tog net soos in Europa herhaaldelik verdring van woon—en werkplekke en hulle kultuurprodukte deurmekaar agterlaat? Of moet ons aanneem, dat die twee tegnieke hier ontstaan en van hier uitgestraal het na die noorde? Ons het geen enkele rede om dit aan te neem nie en daar is baie teën. Maar as ons geen van hierdie twee verklaringe wil aanneem, dan bly daar niks anders oor nie, as om met van Riet Lowe aan te neem dat die twee tegnieke—in Suid-Afrika altans—tot een kultuur behoort.

Is daar dan in Suid-Afrika totaal geen aanwysing nie, om ons in hierdie moeilikheid te help? Laat ons bietjie teruggaan tot 1926, toe ek die Pnielse Kultuur beskrywe het. My verbasing oor die tegnies volmaakte en daarom uiters eenvoudige metode om 'n byl te maak het my daartoe gebring om dit 'n geniale gedagte te noem. Waarom? Wel, sou dit nie geniaal wees nie, van die man wat altyd sy handpikke op 'n moeisame en tydrowende manier gemaak het deur afskilfering van kerne, om op eenmaal daartoe oor te gaan om 'n perfekte handpik te maak van 'n skilfer wat hy deur twee slae uit 'n klip geslaan het en wat nog net 'n half dosyn vry ruwe slae nodig het om af te werk? In

1926 het ek nie geweet van skilfertegniek in vroeër tye nie en ek het my verbaas oor die omswenking en oor die perfeksie. Maar was daar wel 'n omswenking? Vandag weet ons, dat daar selfs in die oudste Stellenbosche Kultuur 'n skilfertegniek toegepas is. Lê dit nie voor die hand nie om aan te neem, dat hierdie skilfertegniek meer en meer ontwikkel is totdat die volmaaktheid van die Pnielse Kultuur bereik is? Dit is in alle geval 'n meer aanneemlike verklaring as die plotselinge omswenking van die kernwerker tot skilferwerker. Maar daarvoor moet ons aanneem 'n ontwikkelingsgang van die skilfertegniek langs die ontwikkeling van die kerntegniek; dit kan dáárom gemaklik gebeur, omdat daar reeds heelwat feite is wat so 'n ontwikkelingsgang waarskynlik maak.

Nou goed. Maar 'n ewewydige ontwikkeling van twee tegnieke vereis tog nie twee verskillende volke nie, dit kan tog baie goed binne een volk plaasvind? As antwoord hierop verwys ek weer na 'n feit. Langs die volmaakte Pnielse byle en handpikke word oorals die pragtigste kernhandpikke gevind. Is dit nou aanneembaar, dat in dieselfde groep van persone dieselfde tipe van werktuig op so 'n uiters verskillende manier gemaak sal word? Ek voel daarvan oortuig dat binne 'n groep die maklikste metode gou sal seëvier en die skilfermetode is die maklikste. Maar tog is die kernmetode gehandhaaf. Dit kan alleen daardeur verklaar word, dat daar groepe van mense was, wat die kerntegniek toegepas het en ander groepe van mense wat op skilfers gewerk het. Nou kan ons verder beweer dat die verskillende groepe van mense dan tog tot dieselfde volk moet behoort het. Maar waarom? Lede van 'n volk het eenderse gewoontes. Die groepe van 'n selfde volk het baie kontak met mekaar. Wat die een doen, doen ook die ander en ook werkmetodes is onderlinge besit. Van jongs af het lede van dieselfde volk geleer om dieselfde werktuie te maak. Op volwasse leeftyd was hulle handig in die metode wat hulle geleer het, maar onhandig vir enigiets wat van buite sou kom. Die mens van die kerntegniek sou nie die metodes oorneem nie van die mens van die skilfertegniek want dit is vreemd, hy is daarin onbeholpe, terwyl hy geleerd is in sy eie. Nee, die groepe wat die verskillende tegniek toegepas het, het behoort tot verskillende volke. Waar ons sover gekom het, behoort dit nie moeilik te wees nie om op grond van die feit, dat naas die volmaakte Pnielse handpik (8) die volmaakte kernhandpik voorkom, saam te gaan met ons Europese kollegas en ook vir Suid-Afrika te erken, dat daar in die paleolitikum twee beskawinge naas mekaar bestaan het.

Daar is egter nog ander feite wat in hierdie rigting wys. Die allermooiste sou natuurlik wees as daar vindplekke kon gekry word, wat alleen òf die kerntegniek òf die skilfertegniek sou bevat. Daar is in die literatuur een vindplek genoem, waarvan die waarskynlikheid groot is, dat dit suiwer tot die skilfertegniek behoort. Dit is deur Dr. T. F. Dreyer bekend gemaak in sy beskrywing van die stratigrafie van die oppervlakte-afsettinge by Mosselbaai. As laag VI (9, bl. 167) beskryf hy 'n rooi laag onder 'n kalkbank,

waarin hy enige "Clacton" skilfers gekry het. Die materiaal is nou in die Nasionale Museum. Daar is 'n stuk of drie, vier skilfers wat 'n min of meer handpikagtige vorm het; 'n aantal ander is net groot, ru skilfers en daar is twee skilfers wat 'n Clactonagtige tegniek vertoon. Die slagveld van hierdie twee skilfers is blykbaar die natuurlike oppervlak van die klip; dit is blykbaar nie vooraf berei deur verwydering van 'n skilfer nie. Die hoeveelheid materiaal is gering, te gering om 'n dwingende bewys te lewer. Maar die voorkome is 'n aanwysing dat dáár moontlik 'n vindplek is van die skilfertegniek alleen. In alle geval behoort hierdie plek deeglik ondersoek te word, voordat 'n aparte skilfertegniek in Suid-Afrika ontken word.

'n Ander vindplek is deur my in die Oranje Vrystaat gekry. Ongelukkig is dit 'n oop vindplek en is daar dus geen gelaagdheid nie. Daar was talryke groot skilfers, so groot soos 'n blad van 'n oktavo-boek. Toe ek en Dr. Hoffman, my assistent, die vindplek ontdek het, het ek nie geweet wat dit beteken nie. Ons het 'n groot aantal van die skilfers versamel en gevind, dat heelwat van hulle die hierbo reeds genoemde Clactonagtige tegniek vertoon. Daar was ook heelwat met sekundêre bewerking. Maar so 'n geselskap was vir ons totaal onbekend; dit kon by geen enkele bekende kultuur of industrie aangesluit word nie. Ook die klippe waar die skilfers afgeslaan was, het ons gekry, maar die was in die meeste gevalle veel te groot om saam te neem. Selfs hier en daar was hulle van die vaste rots afgeslaan. Die grootte van die werktuie het ons die indruk gegee, dat ons met een van die ou kulture te doen het. Maar hoe kon ons dit vasstel? Dit was ons idee, dat in al die ou kulture handpikke voorkom en dus as ons handpikke sou vind sou ons 'n bewys in hande hê. Die vindplek is toe vir ure afgesoek deur vier persone, maar ons het geen enkele handpik gevind nie. Ek het toe gemeen, dat ons hier te doen het met 'n nuwe jong-paleolitiese skilferkultuur, maar die gedagte het nie bevredig nie. Nou egter meen ek, dat hier 'n ou-paleolitiese skilferkultuur voorlê, 'n parallele rigting dus naas die kernkulture. Met die oog op die belangrikheid van die vonds sal die vindplek dadelik aan 'n nuwe ondersoek onderwerp word, waarvan die resultate so gou as moontlik sal bekend gemaak word. Natuurlik wil ek hier nie mee te kenne gee nie, dat ons hier 'n bewys het van die aparte bestaan van 'n skilfertegniek langs 'n kerntegniek, maar dit het daar alle skyn van.

Behalwe die genoemde tipologies-tegniese metodes om die relatiewe ouderdom van klipwerktuie te bepaal, bestaan daar nog andere, waarvan die vernaamste wel is die geologiese metode. Dit berus veral hierop, dat by die vorming van afsettinge die onderste afsetting die oudste is en dat afsettinge wat hoër lê jonger is as die wat voorheen afgesit is. Hierdie eenvoudig gestelde teoretiese geval is egter buitengewoon ingewikkeld in die praktyk.

Afsettinge wat klipwerktuie bevat en wat tegelykertyd van stratigrafiese betekenis is, word in Suid-Afrika hoofsaaklik

gevind in grotte en riviervalleie. Daar is reeds heelwat grotte uitgegrawe en enige van hulle het goeie resultate opgelewer. Van ander grotte kan dit nie gesê word nie, blykbaar is daar te haastig gewerk. As grotatsettinge weinig of geen gelaagdheid toon nie, kan hulle baie onbetroubaar wees. Wat gebeur by die bewoning van 'n grot? Die bewoners bring hulle voedsel en kook of braai dit binne die grot. Daar word vuur gemaak en die as bly lê. Oorblyfsels van die maaltyd soos skulpe en bene word rond gegooi. Die bewoners loop oor die aslaag, plant stokke daarin om velle aan te hang as wande, hulle woel klippe af in die as om kookpotte op te set ens. As die grot verlaat word, kom wilde diere in wat die as omwoel om voedsel daaruit te haal, of om neste daarin te maak, soos muise. Die eerste laag van 'n voet dikte is maar 'n mengelmoes van 'n groot aantal resente bewoners. Ook die volgende paar voet is baie onbetroubaar, want die bewoners het die gewoonte gehad om hulle lyke daarin te begrawe. Wat gebeur nou as 'n graf gegrawe word? Die gat is gewoonlik twee of drie voet diep. Die as word daaruit gehaal en langs die gat opgehoop. Die diepste as kom wel bo op die hoop, maar meestal aan die buitekant daarvan. By die toegooi van die graf word die naaste as eerste geneem en daar nie alles terug gaan in die gat nie bly ook van die diepste materiaal op die oppervlakte lê, saam met moontlike kultuurprodukte wat dit bevat. Hierdeur kan maklik vermenging van 'n ouere kultuurtipe met 'n jongere plaasvind. Ook as nuwe bewoners 'n verlate grot betrek kan daar heelwat storing van die afsetting ontstaan. Hulle het net nodig om die ou plek wat skuins is 'n bietjie gelyk te gaan maak om ouere tipes met nuwere te meng.

Wat afsettinge in riviervalleie betref kan gesê word, dat ons hier met nog moeiliker probleme te doen het is in grotte. Daar is in Suid-Afrika nog maar min gedoen om hierdie probleme op te los. Onlangs egter is daar deur die Geologiese Opname en die Argeologiese Buro 'n uitgebreide ondersoek ingestel langs die Vaalrivier (1). Daaroor is 'n werk gepubliseer van 130 oktavo bladsye en talryke plate en kaarte. Die uiterlike indruk van hierdie publikasie is, dat hiermee die argeologiese kulture stratigrafies vir goed vasgelê word, maar die leser wat dit dink sal bitter teleurgestel wees as hy die boek neerlê. Die saak is vir die argeologiese wetenskap van die grootste belang en omdat die gesag van die direkteur van die Argeologiese Buro daaraan verbonde is, sal die werk ongetwyfeld groot invloed uitoefen by mense, wat nie die moeite neem om dit van A tot Z deur te worstel en wat nie voldoende met die behandelde streek bekend is nie, om dit krities te kan lees. Dit is daarom dat ek hier die vernaamste resultate van die werk wil bespreek.

Die doel van die werk was om na te gaan of daar nie verskil in ouderdom kon vasgestel word nie in die afsettinge van die Vaalrivier, veral ook om daardeur die Argeologie behulpsaam te wees met die vasstelling van die relatiewe ouderdom van die klipwerktuie. Die resultate van die ondersoek sou miskien ook

gebruik kon word om die klimaatstoestande van die Vaalrivier in die verlede te bestudeer en om die ouderdom van die afsettinge met behulp van fossiele te bepaal.

Dit moet dadelik gesê word dat die geoloë daar uitstekend in geslaag is om die geologiese geskiedenis van die rivier vas te stel. Dit is veral interessant om te sien watter rol die gangdamme in die rivier gespeel het. Ook het hulle 'n poging gedoen om die klimaatstoestande in die Ou-Steentydperk vas te lê. Ek moet egter erken, dat daar 'n mate van twyfel oor bly as daar geen verklaring gegee word nie, waarom die tweede en derde reentyd wel invloed gehad het op die syriviere maar nie op die Vaalrivier self, b.v. by Windsorton nie. Ook sou 'n verklaring baie welkom wees, waarom die Vaalrivier gedurende die eerste reentyd verskillende terrasse kon sny en so baie gruis daarop afset terwyl die riviere wat in die Suidelike Oranje Vrystaat bestudeer is, slegs afsettinge van die tweede reentyd toon. Die belangrikste gedeelte vir die argeoloog is die beskrywing van die afsettinge in die vallei van die Vaalrivier. Daar is geen ouderdomme bepaal met behulp van fossiele nie, maar daar is terrasse gevind, wat verskillende hoogtes inneem en klaarblyklik in verskillende tyde afgesit is. Die beskrywing van die verskillende afsettinge langs en in die rivier gee besondere voldoening, waar hulle hul aan suiwere geologiese argumentasie hou. Ongelukkig is dit b.v. nie die geval nie by die belangrikste gedeelte wat ondersoek is, n.l. die by Windsorton. Dit bly nie by 'n enkele verklaring nie, daar kom al gou 'n tweede wat die eerste belangrik wysig. Ten slotte kom daar 'n derde, wat die twee vorige verklaringe geheel onderstebo gooi, en dit op argeologiese oorweginge, nie geologiese feite nie. Dit is hier waar baie van die werktuie van die Ou-Steentydperk gevind is. Op die waarneminge wat hier plaas gevind het is argeologiese gevolgtrekkinge opgebou van wye betekenis en dit is daarom noodsaaklik om die berig oor die geologiese bevinding noukeurig te volg. Die ou gruislae bo op die koppe sal ons nie op die oomblik behandel nie en ons sal ons nou alleen besig hou met die jongere gruislae.

Op bl. 26 word twee gruisterrasse beskrywe. Die laagste terras, van 25 voet hoogte, lê wel aan altwee kante van die rivier, maar sy rand kan aan die ooste kant net vir 'n paar honderd treë gevolg word. Aan die westekant loop hierdie terras vanaf die rivier tot aan die hoogtes, terwyl dit na die noorde begrens word deur 'n tweede terras, wat op 'n hoogte lê van 40-50 voet. Hierdie tweede terras is klein aan die westekant van die rivier maar uitgebreid aan die oostekant waar sy algemene hoogte bo die rivier omtrent 35 voet is, wat na die ooste styg tot 55 voet. Al hierdie gruis is bedek met sand waar die gruis nog nie deur die mens bewerk is nie. Daar die gruislaag 'n onreëlmatige bo-oppervlak het, is die dikte van die sand onreëlmatig, op sommige plekke baie dik en op ander baie dun. Dikte en geaardheid van gruis en sandbedekking is bestudeer in talryke gate, wat deur diamantdelwers gemaak is of word. Klipwerktuie van die

" Stellenbosche Kultuur " word baie gevind op die volgende plekke van die tweede (hoogste) terras: Larsen, Brown, Homestead. Vanaf die pont noordwaarts is hulle skaars. In die tweede terras het die geoloë talryke ou rivierlope gekry uit die tyd toe die rivier hier talryke meanders gehad het. Dit is in korte trekke wat die geoloë hier gevind het.

Op bl. 45 gee die geoloë die volgende verklaring van die feite wat hulle aangetref het: By die begin van die reentyd was die rivier in staat om 'n platform te sny wat 40 voet bo die teenswoordige rivierbed lê en wat voorkom in die noordelike gedeelte van die dorp Windsorton en die noordelike Wedburgstreek. Met die vermindering van die reenval is hierop gruis afgesit en daarna sand. Toe het 'n tweede reentyd begin. Die rivier het 'n tweede platform gesny op 'n hoogte van 20 tot 30 voet bo die teenswoordige rivier. Die platform lê onder die hele Riverviewstreek en toe die reenval verminder het, is hier weer gruis op afgesit en later sand. Toe het 'n derde reentyd gekom. Die rivier was toe omtrent in sy teenswoordige loop en 'n derde platform is gesny ongeveer 10 voet onder vandag se bed. Hierop is nou al weer gruis afgesit.

Uit dit alles kan kort saamgevat word, dat die geoloë bo die bed van die rivier van vandag twee terrasse gekry het, wat elk met gruis en sand bedek is. Die derde terras en gruislaag is vandag se rivierbed.

Nou is deur hierdie terrasse snitte gelê en tekeninge is daarvan gegee. Daar is 'n snit dwars oor die Vaal van Wedburg na Windsorton. Hierop is aangegee aan die Wedburg kant 'n gruisbank met die naam " Deep Gravel." Dan lê daar 'n gruisbank in die Vaalrivierbed, wat laer lê as die eersgenoemde en ook " Deep Gravel " genoem word. By Windsorton lê 'n gruisbank, hoër an die ander twee en die word ook " Deep Gravel " genoem. Met " Deep Gravel " word hier blykbaar Jongere Gruis bedoel. 'n Voetnoot by die tekening sê, dat die eerste gruis " Deep Gravel II " is, die tweede, in die bed van die rivier, is " Deep Gravel III " en die derde by Windsorton " Deep Gravel I. " Nou is dit reeds baie eienaardig dat die wel-oorwoë idee wat die geoloë gehad het toe die tekening gemaak is, verander moes word, maar die verandering is boondien nie korrek nie. Die lyn van die snit is op Pl. I aangegee en by Wedburg gaan hy deur die terras van 35 voet wat tot by die Homestead strek en soos hierbo aangehaal sou dit dieselfde terras wees wat by Windsorton lê. Waarom moet hulle dan nou op eenmaal verskillend wees, terwyl die geoloë in hul geskrewe verslag blykbaar geen rede kon vind nie om die twee terrasdele aan beide kante van die rivier van mekaar te skei en tot twee verskillende terrasse te maak? Die geoloë gee geen rede nie en dus kan ons hulle verandering nie aanvaar nie. In die snit Wedburg-Windsorton is daar maar twee gruisterrasse, die een in die rivierbed en die ander een aan beide kante langs die rivier.

Wat die sandafsetting betref het ons in die een geskrif ook 'n merkwaardige verandering van meening. Eers (bl. 26) is daar op elk van die twee genoemde terrasse 'n sandlaag. Op bl. 44 egter word gesê dat die sand lê op 'n baie ongelyke gruisvloer en dat drie algemene hoogtes kan onderskei word n.l.: Rond Wedburg en Wedburg-koppie en by Windsorton lê die vloer van die sand 48 voet hoog. In die Suidweste, oos van Larsen en die "Fissure" lê die vloer van die sand 40 voet hoog. Oor die sentrale gedeelte van Riverview lê die vloer van die sand 24 voet hoog. In die eerste plek wil ek hier opmerk, dat die genoemde vindplekke waar die vloer van die sand 40 voet hoog lê, almal op die eerste terras lê van 40 voet. Daar moet onthou word, dat hierdie terras aan die Wedburgkant van die rivier, maar 35 voet hoog is. Op bl. 45, hierbo gesiteer, word gepraat van 'n 40 voet platvorm en 'n 20-30 voet platvorm wat onder die hele Riverviewstreek lê. Miskien was die eerste terrasindeling 'n vergissing en moet ons nou aanneem, dat daar 'n vloer van 40 voet hoog aan albei kante van die rivier is met gruis op. Dan 'n vloer van 20—30 voet hoog, net aan een kant van die rivier, ook met gruis op en dan 'n derde vloer, wat nou onder die rivierbed lê en wat bedek is met gruis tot 25 voet bo die rivierbed. As dit so is, dan het die geoloë geen merkbare oorgang kan vasstel nie tussen gruis op vloer 40 en gruis op vloer 30, ek bedoel, dit vorm blykbaar een deurlopende laag. Uit Pl. VI wat die argeologiese gedeelte van die werk illustreer blyk, dat daar tussen die gruis op die 30 vloer en die van die rivierbed ook geen grens in die veld is nie; dit is eenvoudig een deurlopende laag. Maar dit is nie al nie. Op bl. 127 kom die geoloë ons vertel, dat die argeoloog gevind het dat daar op die gruis van Larsen, dus Gruis II van die verbeterde indeling, werktuie lê wat hy jonger reken as Gruis III. Daarom, sê die geoloog, is sy hele indeling van die sand foutief. Die sande wat op die 48 voet, die 40 voet en die 30 voet vloere lê is dan nie van verskillende ouderdom nie. Hy erken nou, dat die sande geen litologiese en geen stratigrafiese verskille toon nie en omdat die argeoloog nou tipologiese moeilikhede het, nou spring die geoloog om en verklaar sy formasies jonger as die gruis in die rivierbed. Voorwaar, 'n dergelike tegemoetkomende geologie, wat sy ouderdomme vasstel op gegewens wat die argeoloog verstrek is van geen waarde vir die argeoloog wat daarmee die ouderdom van sy werktuie wil bepaal nie.

Nóu sê die geoloog, dat die gang van sake in die Vaalrivier as volg was: Elke reentyd het die sand van die vorige periode weggewas. Na die vorming van Gruis III is die hele streek bedek met 'n sand, wat nou sand III genoem word. Dit beteken dus, dat toe Gruis III, die wat nou in die rivierbed lê, gevorm is, die hele oppervlakte van al die ander gruis oop gelê het. Maar dit beteken verder, dat die klimatologiese veranderinge wat in die eerste reentyd sou plaasgevind het, nou alleen berus op sekere vloere wat in die ondergrond gesny is en dat die droëre periodes, waarin sand sou afgesit word, nou op geen enkele bewys berus nie.

Wat hierdie vloere betref glo ek nie dat hulle 'n bewys is van 'n reentyd nie. Hulle is nie gesny deur die rivier in 'n groot vloed nie. Die platvorms is gemaak deur die langsame verskuiwing van die meanders waarvan talryke oorblyfsels aanwesig is in die vorm van slote in die ondergrond; in hierdie slote het die meanders 'n tyd stil gestaan. Daar is feitlik nie twee (of drie) terrasse nie; daar is 'n groot aantal; met ander woorde daar is geen terras, want die rivierbed het hier blykbaar geleidelik laer geword. Ons het hier die beeld van 'n rivier met 'n vry gelykmatige geskiedenis van die eerste begin wat ons kan nagaan tot vandag. Daarom is die gruislaag wat agtergelaat is één deurlopende laag. Die vloere kan ook nog op 'n ander wyse verklaar word, b.v. deur afwisselende snelheid in die afbraak van gangdamme. 'n Vloer sou dan die tyd voorstel waarin die afbraak baie langsaam gaan. Dit blyk nou, dat die hele eerste reenperiode feitlik geen grond het nie. Die enigste grond wat miskien nog aangevoer kan word is die aanwesigheid van gruis. Maar is die aanwesigheid van gruis in 'n rivierbed wel 'n voldoende bewys vir 'n reenperiode? As dit so is, dan het ons vandag seker 'n reenperiode, want die Vaalrivier se bed lê toegepak met gruis? Maar ons het dan gedink dat ons nou in 'n droë tyd lewe? Nee, gruis in 'n rivierbed is vir my 'n bewys van weinig water. Waarvandaan kry die Vaalrivier se bed die gruis wat nou daar in lê? Gedeeltelik van hoër op, met sterk watervloede. Maar hoofsaaklik van die ou gruis van vroeër tye, wat deur meandervorming of gewone slingering van die rivier weer in die bed gebring word deur onderwoeling. Hierdie meandervorming is 'n bewys van weinig krag. Ek skryf dit toe aan weinig water. Moontlik kom dit deur geringe verval deur opdamming. Wat die oorsaak ookal is, ek gaan dit hierby laat. Dit is duidelik dat die klimatologiese geskiedenis van die Vaalrivier soos dit gegee is, nie kan aanvaar word nie. Dit is die taak van die geoloë om die oplossing te vind.

Wat leer ons nou uit hierdie geologiese gegewens met betrekking tot ouderdom en voorkome van Argeologiese voorwerpe? Ons het die indruk gekry van stratigrafiese opeenvolging en nou wil ons graag sien watter resultate die argeoloog in hierdie opsig bereik het.

'n interessante hoofstuk in die argeologiese gedeelte van die verslag is dié oor stratifikasie. Hierin word gewys op die oudste gruis wat bo op die hoogtes lê, die jongere gruis, wat in die engere Vaalrivier bed voorkom en die jongste gruis, waaroor geen woord in die geologiese gedeelte gesê word nie en wat dus blykbaar 'n vinding is van die argeoloog.

Oor die oudste gruisafsetting word hier gesê, dat dit geen werktuie bevat nie, tensy op plekke waar die gruis omgedelwe is. Daar word op gewys, dat al kom vars en gerolde werktuie by mekaar voor in situ in 'n gruisbed, dit glad nie noodsaaklik is nie, dat werktuie en gruis van dieselfde ouderdom moet wees. Daar word 'n voorbeeld gegee om hierdie feit te staaf. Die werktuie is hier ingebring deurdat die mens die klippe omgedelwe

het om geskiktes te soek om werktuie van te maak. Die afgewryfde voorkome van die werktuie kom deurdat hulle in klein lopies verspoel is of dat sand en gruis deur lopies oor hulle gevoer is.

By die behandeling van die Jongere Gruisafsetting word gesê, dat daar op sommige plekke langs die rivier drie terrasse is, op ander plekke twee en soms is daar maar een; hierdie formasies sou afhanklik wees van natuurlike damme in die rivier. Dan word die terrasse van Windsorton genoem met die opmerking, dat die gruis op hierdie terrasse afgesit is gedurende die drie periodes van die eerste reentyd. Nou is dit wel duidelik, dat as die terrasse die gevolg is van damme, hulle min te doen het met klimatologiese veranderinge; in alle geval moet dan die klimatologiese aandeel nog bewys word. Verder blyk dit, dat "Pre-Stellenbosch"-werktuie voorkom in Gruis II. Alleen gerolde "Stellenbosch I"-werktuie kom voor in Gruis II en III. Alleen gerolde "Stellenbosch II"-werktuie in Gruis II en III. Werktuie en werkplek-oorblyfsels van "Stellenbosch III" word gevind in Gruis II en in die sand wat daarop lê. Werktuie van "Stellenbosch IV" word gevind in Gruis III. As ons dit alles samevat, dan blyk dit, dat Gruis II bevat: "Pre-Stellenbosch," "Stellenbosch" I, II, III. Gruis III bevat, "Stellenbosch" I, II en IV.

Nou kom 'n interessante verhaal oor "Stellenbosch V." Die geoloog sê hiervan die volgende: Nadat die geologiese werk aan die Vaalrivier klaar was, het Prof. van Riet Lowe die argeologiese werk by Windsorton voortgesit en belangrike informasie verkry met betrekking tot die ouderdom van sekere werktuigtipes en die bedekkende sande by Larsen se plek. Dit blyk, dat werktuie van 'n ontwikkelde stadium (Stellenbosch V) steeds op die Jongere Gruisafsetting II voorkom by Larsen en Prof. van Riet Lowe is oortuig dat hulle 'n latere stadium voorstel as die in die Jongere Gruis III nader by die rivier. Dit bewys, dat die sande wat op Gruisafsetting II lê jonger is as Gruisafsetting III.

Die argeoloog vertel dat hy die "Stellenbosch" V werktuie reeds op Larsen se plek versamel het, voordat die geoloë die bestaan van die drie afdelinge in die Jongere Gruisafsettinge en sande by Riverview herken het. Hulle was vars, het op Gruisafsetting II gelê, was verder ontwikkelde tipes as die ander werktuie van die vindplek en selfs as die van Gruisafsetting III by plek VI. Nadat hy sy artikel geskrywe het, laat die geoloë hom weet, dat die sand wat op Gruisafsetting II by Larsen lê, Sand II is; dit is ouer as Sand III. Toe moes hy sy artikel oorskryf en "Stellenbosch" V en III bymekaar sit. Daarna het geblyk, dat die meerderheid van vars werktuie op Gruisafsetting II en in die bedekkende sand beter in sy oorspronklike indeling gepas het.

Hieruit blyk dat die sogenaamde "Stellenbosch" V 'n aantal werktuie omvat, wat om suiwer tipologiese redene afgeskei

word van III en IV. Daar word geen besondere tegniek aangegee nie; net vorm, grootte en materiaal. Om nou volledig te wees kan ons dus sê, dat die werktuie as volg voorkom:

Gruisafsetting II bevat: "Pre-Stellenbosch," "Stellenbosch" I, II, III en V.

Gruisafsetting III bevat: "Stellenbosch" I, II en IV.

Nou verwys ek weer na die opvatting van die geoloë, hiervoor genoem, dat elke reentyd die sand van die vorige periode weggewas het. Toe gruisafsetting III ontstaan het, was daar dus geen sand op II en I nie. Dit wil sê hulle was oop en toegankelik vir wie ook. Nou is in Gruisafsetting II "Stellenbosch" V gevind; dan is daar ook geen enkele rede waarom "Stellenbosch" IV nie daarin sal voorkom nie. Dit sou óók heel onbegryplik wees, waar "Stellenbosch" II en IV in Gruisafsetting III voorkom, dat "Stellenbosch" III nie daarin sou voorkom nie. Die gevolgtrekking is dus, dat al die klipkulture van die Ou-Steentydperk voorkom in Gruisafsetting II sowel as in Gruisafsetting III. Met ander woorde, daar is geen sprake van argeologiese verskille tussen Gruisafsettinge II en III nie. Hierbo het ons reeds gesien, dat daar ook geen stratigrafiese verskille tussen die twee is nie. Maar waarvandoon kom dan die indeling in die talryke "kulture?" Die werktuie word alleen van mekaar onderskei na vorm en voorkoms, d.w.s. alleen deur toepassing van die tipologiese metode. Ons is, wat dit betref, dus nog geen stap verder nie as 1926, toe ek die eerste indeling van die paleolitikum gegee het. Maar daar is ook baie verskil van mening oor wat onder tipologie moet verstaan word. Die begrip het in Europa tot 'n buitengewone warboel gelei. De Mortillet het geprobeer die tipologiese bepaling van kulture op 'n stratigrafies-kronologiese basis te plaas, d.w.s. 'n kultuur was bekend as die habitus van die werktuie van 'n tipiese vindplek in 'n bepaalde laag bekend was. Ander werktuie kon dan hiermee vergelyk word. Ongelukkig was de Mortillet se tipevindplekke nie suiwer nie en is die werktuie wat daar gevind is onderverdeel. Nou gaan die tipologiese metode van sy stratigrafiese basis af en dit is waar ons in Suid-Afrika in die Paleolitikum staan. Ons het hier geen stratigrafiese houvas nie en tog wil ons relatiewe ouderdomme bepaal. Patina faal in Suid-Afrika geheel. Of 'n werktuig meer of minder afgeslyt is, kan ook nie 'n kriterium vir ouderdom wees nie. Onder tipologiese metode van ouderdombepaling verstaan ek die toepassing van alle eienskappe wat 'n werktuig toon. Daar is veral drie eienskappe wat hier van belang is: Vorm, grootte en wyse waarop die werktuig gemaak is. Hoe meer eienskappe hoe beter. Van Riet Lowe skyn te meen, dat vorm en grootte van geringe betekenis is waar hy sê: "Ons is besig om gou die stadium te bereik waar tipologie van weinig betekenis is en daarom keer ons nou na tegniek (1, bl. 107). Ek stem nie met hom saam nie. Tegniek alleen is net so onbevredigend as vorm alleen of grootte alleen; die drie

bymekaar, dus die tipologiese metode in sy gehééł is selfs baie onbevredigend in vergelyking met die stratigrafiese metode.

Dit is hierdie onbevredigende tipologiese metode wat toegepas is om die " Pre-Stellenbosch en " Stellenbosch " I tot en met V, dus ses " kulture," van mekaar te skei. Nou is dit duidelik dat by die beoordeling van grootte, vorm en tegniek van 'n werktuig 'n meer of minder groot persoonlike faktor saamwerk. Moet egter 'n groep werktuie uit riviergruis in verskillende kulture gesorteer word, dan is die persoonlike faktor van nog groter betekenis. Om 'n voorbeeld te gee: Van Riet Lowe gee in Plaat XXV, fig. 1 die afbeelding van 'n byl, wat hy by "Stellenbosch " III geplaas het en wat ek sonder aarseling (na die figuur te oordeel!) sou plaas by my Pnielse Kultuur. Later het van Riet Lowe hierdie byl geplaas by sy " Stellenbosch " V. In plaat XXVII, fig. 2 beeld hy 'n dergelike byl af, wat blykbaar in vorm en tegniek geheel ooreenkom met die eersgenoemde; hy is wèl heel wat groter. Ek sou hierdie byl by my Pnielse Kultuur plaas; van Riet Lowe plaas hom by " Stellenbosch " IV.

Wat die ou kulture van die Steentydperk betref is ons dus ongelukkig aangewys op die tipologiese metode. Hoe staan dit nou met die groep wat van Riet Lowe die Fauresmith-Kultuur noem? ,, Fauresmith I " sou voorkom in die " Jongste Gruisafsetting."

Die geologiese verslag noem alleen 'n gruis in die bed van 'n lopie in die suidelike gedeelte van die Riverview-Windsorton streek, wat ooreenkom met die " Jongste Gruisafsetting " van die Rietrivier, omdat dit werktuie bevat van die vroeë Fauresmith Kultuur. Die argeoloog noem dit die belangrikste vindplek wat nog gevind is (bl. 73).

Die gruis in die lopie kom ten slotte êrens vandaan. Waarvandaan? Die lopie loop alleen deur die gebied van die " Jongere Gruisafsetting " en sy sandbedekking. Daar is geen harde rotse nie wat die moedergesteente kon wees van die gruis. Alleen in 'n paar slote wat in die lopie uitmond kom Dwyka aan die dag en vir 'n kort end loop hy langs lava. Het die Dwyka en die lava die gruis gelewer? Die geoloë sê daar niks van nie en tog is dit belangrik om te weet. In die argeologiese gedeelte word gesê dat die gruis drie voet dik is. Dit is nogal baie om te lewer vir 'n enkele dagsoompie van rots in 'n sloot. Dit wil my voorkom, dat die gruis sy ontstaan te danke het aan die Gruisafsettinge II en III. In die deursnit van die argeologiese gedeelte word die spruitbed baie naby Gruisafsetting III aangegee, d.w.s. dat die spruitbed byna so diep is, as wat die sandbedekking dik is. In die geologiese gedeelte is 'n snit wat aantoon dat Gruisbank II telkens weer aan die oppervlakte of naby die oppervlakte kom. Dit is dus glad nie onmoontlik nie, dat die gruis van die lopie niks anders is nie as gruis van Gruisafsettinge II en III. Die geoloë laat ons hier in die duister, maar die argeoloog net so goed. Alleen die geoloë sê, dat die

gruis van die lopie baie werktuie bevat van die vroeë „Fauresmith-kultuur." (bl. 47). Die argeoloog sê van die voorkome van sulke werktuie in hierdie gruis op die " belangrikste vindplek " niks nie. In sy beskrywing van die „ Fauresmith-Kultuur " maak hy alleen gebruik van werktuie wat voor die dag gekom het onder die rooi oppervlakte sand en op die oppervlakte van die verkalkte sand, nie van werktuie uit die " Jongste Gruis " nie.

En wat is dan die werktuie van die „ Fauresmith I Kultuur?" Dit is handpikke en byle en enige growwe skrapers op skilfers; verder is daar kerne waar groot skilfers en ander waar lang skilfers afgeslaan is en hamers. In die eerste plek wil ek hier opmerk dat die werktuie gevind is op die geërodeerde oppervlakte van die verkalkte sand (bl. 112). Die oppervlakte is dus 'n tydlang oop en toegankelik gewees vir die mens wat die „Fauresmith-werktuie " gemaak het sowel as vir mense van latere kulture, soos b.v. van die Mosselbaaise Kultuur. Dit is dus baie goed moontlik dat die twee afgebeelde kerne tot daardie kultuur behoort.

Dan sou ek graag wil vra wat die verskil is tussen " Stellenbosch V " en " Fauresmith I " as ons die handpikke in oënskou neem. Fig. 2 van Pl. XX (" Stellenbosch V ") verskil blykbaar in geen enkel opsig van fig. 1 van Pl. XXX (" F." 1). Figure 6 en 4 van Pl. XX („ St." V) kom heeltemaal goed ooreen met figure 2 en 4 van Pl. XXX („ F." 1). Van Riet Lowe sê hiervan (bl. 112), dat die handpik seker nie fyner in afwerking is nie as die van " Stellenbosch V." Die bewerking is onhandiger. Praat nou van tipologiese beoordeling! Die genoemde fig. 4 van Pl. XX het 'n merkwaardigheid geword. Op bl. 107 noem van Riet Lowe hierdie werktuig as voorbeeld van hoe 'n groot fout gemaak kan word as dit tipologies beoordeel was. Hy sê, as hierdie klein netjies afgewerkte werktuig los gevind was, sou hy dit byna sonder aarseling in die mees ontwikkelde „ Fauresmith " geplaas het, waar dit deur 50 voet afsetting van geskei is. Nou behoort dit tot " Stellenbosch III." Egter, aan die end van sy boek plaas hy dit om die genoemde tipologiese redes in 'n nuwe kultuur " Stellenbosch V!"

Blykbaar lyk die handpikke van die twee " kulture " op mekaar as een eier op die ander. Ander vergelykbare werktuie is die byle.

Daar word vier afgebeeld, drie kleintjies en 'n grote. Die groot een kom volkome ooreen met eksemplare van die Pnielse Kultuur. Die drie kleintjies ken ek geen voorbeelde van in ander kulture nie. Ook nie van die twee groot skilfers. Dit sou dan die tipologiese verskil wees met " Stellenbosch V." Boondien word by die laaste kultuur nog 'n paar skilfer-handpikke beskryf, wat nie by die " Fauresmith I " genoem word nie, maar wat tipologies verder ontwikkel is. Daar word ook byle by geplaas wat sonder twyfel tuishoort by " Stellenbosch III " (waar dit op lê) of is dit miskien Stellenbosch IV?

Tipologies kan ek geen verskil sien nie tussen die grootste gedeelte van die werktuie van " Stellenbosch V " en " Fauresmith I." Hulle behoort na my opvatting tot dieselfde kultuurfase. Maar hoe moet dan die verskil in " stratigrafie " verklaar word? Wel die geoloë sê tog, dat die meeste sand van die voorafgaande Gruisafsettinge afgespoel was na die afsetting van die laaste gruisbank. D.w.s. dat die hele streek hier oop gelê het. Nou kan ek my nie voorstel nie, dat die hele streek toe dadelik met sand bedek is. Van sy diepste bed het die rivier geleidelik gerys, eers deur gruisafsetting en toe die water baie swak geword het deur sandafsetting. Die eerste sand is afgesit by die plek waar sy bed in die vaste rots vandag nog die diepste is, d.w.s. by Amandelhoogte. Dit kon juis die tyd gewees het, dat die " Stellenbosch V " mense verder van die rivier af hulle werktuie op die ou gruis gemaak het en hulle ook op die sandwal by die rivier laat lê het. Daarna is miskien geleidelik die hele streek deur meanders van die rivier, met sand opgevul. Hier is een aanneemlike verklaring waarom " Stellenbosch V " en " Fauresmith I " dieselfde kan wees. Maar daar is miskien nog 'n hele aantal ander aanneemlike verklaringe, want die geoloog wat die geskiedenis van gruis en sand in 'n rivierbed in besonderhede en met sekerheid kan ontrafel moet nog gebore word.

As nou " Stellenbosch V " en " Fauresmith I " dieselfde kultuurfase verteenwoordig, dan sou hulle tog iets anders wees as " Stellenbosch III of IV?" Ook dit is nie noodsaaklik nie. Ek het in die Rietrivier die pragtigste klein handpikke gevind midden tussen 'n menigte Pnielse byle binne in 'n dik gruisbank. Hierdie handpikke was vars; die byle was gedeeltelik gerol en vars. Hier dus " Stellenbosch V " of " Fauresmith I " tesame met Stellenbosch III " binne-in 'n dik gruisbank onder 30 voet verkalkte sand. Hierdie fynste handpikke gemaak deur herhaalde afskilfering van die rande af, naas werktuie van mense wat 'n handpik met 'n paar slae kon fabriseer! Alleen as hier twee beskawinge langs mekaar bestaan het, is dit verklaarbaar. Ons sou dan hier hê die Pnielse Kultuur van die Skilferbeskawing en 'n fase van die Vaalse kultuur van die kernbeskawing. 'n Aparte " Fauresmith I " is in alle geval onbestaanbaar naas " Stellenbosch V " en vermoedelik moet hierdie fase in tyd nog verder agteruit.

Hoe staan dit met ,, Fauresmith II "? Volgens van Riet Lowe (bl. 91) lê hierdie fase van die " Fauresmith-Kultuur " op die afsettinge wat die " Jongste Gruis " bedek. Hierdie afsettinge is som 20 voet dik. Hy noem die vindplek op die plaas Brakfontein 'n woon- en werkplek en 'n klassieke snit. Ek sou die woord klassiek alleen gebruik vir dinge wat in verband staan met Grieke en Romeine; as hiermee dus bedoel word oudbekende dan stem ek nie saam nie, want hy maak dit nou eers bekend, hoewel beroemde argeoloë die plek enige jare gelede besoek het. Word bedoel dat dit die tipiese vindplek is dan

verheug dit my baie, want ek ken elke vierkante voet van die omgewing van die spruit vanaf die plek waar die hoofpad Koffiefontein-Fauresmith oor die spruit gaan tot waar hy in Rietrivier val. Die werktuie wat as " Fauresmith II " beskryf word is versamel van onder tamelik vaste sandduine op verkalkte vuil grond op sommige plekke en tufkalk op ander plekke. Daar word gesê dat versamelinge van hierdie vindplek te sien is in London en Parys. Ek weet nie hoe groot die versamelinge in die buiteland is nie maar ek kan u meedeel wat die Nasionale Museum van die spruit besit. Die totale hoeveelheid werktuie wat ons het van hierdie spruit vanaf die groot pad tot omtrent 300 treë virby die drif van die pad na die dam in Rietrivier is 'n 2,000 stuks en van hulle is sorgvuldig opgeteken waar hulle presies gekry is.

Van Riet Lowe sê, dat al die werktuie wat hy afbeeld gevind is onder vry harde sand. Hy het natuurlik nie gegrawe nie; hy bedoel waarskynlik dat hulle in die kaal kalkholtes gelê het, waar die sand vroeër op was en nou weggewaai het, miskien wel half vas in die sand. Die werktuie bestaan uit klein handpikke, byle, bewerkte skilferpunte, tipiese slagmesse, Levallois-skilfers, kerne, lang en smal skilfers, gooiklippe en beitels. Van die byle sê hy, dat hulle in geen enkele opsig onderskei kan word nie van karakteristieke " Stellenbosch III " vorme en dat dit onmoontlik is om uit te maak of hulle tot die kultuur behoort of dat hulle op die plek gebring is van 'n laere horisont. Sy eie opvatting is, dat hulle nie deur " Fauresmith II " mense gemaak is nie, maar net gebruik is nadat hulle dit van 'n ouere " Stellenbosch " horisont verkry het. Van die skrapers sê hy (bl. 113), dat hulle 'n merkwaardige ooreenkoms met die van " Smithfield I " het.

My eie waarneminge langs hierdie spruit gee ek aan die hand van sketskaartjies en enkele snitte. Figuur I gee 'n skets van die loop van die spruit wat van Brakfontein noordwaarts loop oor Valsfontein, Telegraafsfontein en Goede Hoop om dan in Rietrivier te val. Die snitte oor hierdie gebied is weergegee in figure 3 en 4. Die opname is gemaak met plansjet en alhidade en dus alleen noukeurig genoeg vir die doel wat hy moet dien. Volg ons die spruit stroomop van naby die werf van Goede Hoop van af 'n hoë wal noord van die drif van die plaaspad dan word tussen die punte A en B aan die oostekant leisteen en aan die westekant diabaas in die spruitbed aangetref. Daarop lê aan altwee kante kalk, wat weer bedek word deur kalksand; die laaste word bedek deur taamlik vaste waaisand. Aan altwee kante lê werktuie van die Koningse Industrie versprei oor die kalksand- en kalk-oppervlakte; aan die westekant lê hulle ook op die diabaas. By punte D, F en H word dieselfde opeenvolging aangetref: lei, kalk, kalksand, sand. Maar by C word die lei ommiddellik bedek deur sand, terwyl daar by E net 'n dun lagie fyn gruis op die leisteen lê. Vanaf die drif van die plaaspad tot byna by punt H en dan ook by hierdie punt self is daar

honderde werktuie van die Koningse Industrie versamel. Aan die oorkant van die spruit egter, by punt E is die Koningse Industrie nie suiwer aangetref nie; hier lê ook werktuie van die Mosselbaaise Kultuur. By D, F en H lê die werktuie op die kalksand, onmiddellik onder die sand. Die wat op die kalk lê is baie duidelik daarnatoe afgespoel van die hoëre kalksand. By E lê die werktuie direk op die leisteen. 'n Bietjie suid van E—F loop 'n groot spruit aan die oostekant in die Brakfonteinse spruit. Tussen die twee lê 'n baie ryke en merkwaardige veld wat klipwerktuie betref. 'n Snit oor die punte I—H toon die volgende: Die Brakfonteinse spruit loop oor leisteen, die bed van die spruit is skoon. Die spruitwal aan die kant van H toon 'n kalkbank van omtrent 6 voet dikte, waarop 'n laag kalksand lê wat miskien 2 voet dik is, wat dan weer bedek word deur omtrent 4 voet waaisand. Hierdie waaisand vorm naby die spruit geen aaneengeslote bed nie, maar bestaan uit afgesonderde gedeeltes waartussen die kalksand tevoorskyn kom. Dit is op hierdie kalksand waar die Koningse werktuie lê, nie op die kalk nie. Op die kalk is hier 'n aantal klippe aangetref, waartussen twee werktuie gevind is, wat nie tot die Koningse Kultuur behoort nie. Dit is twee lang skilfers maar hulle is nie tipies genoeg om hulle by die Mosselbaaise Kultuur te plaas nie. Die wal van die Brakfonteinse spruit aan die kant van I vertoon nie so 'n dik kalkbank as aan die kant van H nie. Dit is miskien 4 voet dik en word bedek deur 'n laag kalksand van omtrent 4 voet dik, waarop by I 4 voet waaisand lê. Die helling vanaf I na die oostelike spruit vertoon egter 'n ander beeld. Die spruit lê 'n paar voet dieper as die Brakfonteinse spruit en sy bed is met sand bedek; die verval in die Brakfonteinse spruit is hier blykbaar groter. Vanaf die bodem van die oostelike spruit na I toe word eers 4—5 voet sand aangetref, daarop 'n 4 voet kalksand en daarop weer 4 voet sand. Dus hier lê kalksand op sand, nie op kalk nie soos ons tot nog toe aangetref het. Die oostelike wal van die oostelike spruit vertoon alleen leisteen. Die sand by I is 'n eiland omring deur 'n groot oppervlakte kalksand. Op hierdie kalksand rondom die eiland is 'n groot aantal Koningse werktuie versamel. Hier was geen werktuie van ander kulture nie. Merkwaardig in hierdie snit is, dat die kalk van die een kant aan die ander kant verteenwoordig word deur sand. Dit wys op die waarskynlikheid, dat die verkalkingsproses nie 'n gelykmatige was nie. Miskien was die water van die Brakfonteinse spruit kalkryker en moet die verkalkingsproses dus 'n meer plaaslike verklaring kry; dan sou egter die verklaring van kalkbanke as die resultaat van een bepaalde droogtetyd, dus as 'n bepaalde stratigrafiese horisont soos in die geologies—argeologiese verslag gedoen word, nie die juiste kan wees nie.

Gaan ons verder suidwaarts met altwee spruite dan kom ons by die punte K, L, M en N. By N is min of meer dieselfde toestand aangetref as by H. By M lê 'n groot uitgestrektheid leisteen langs die spruit en die veld tussen M en L is 'n groot oop

vlakte van kalksand met hier en daar 'n kol waaisand bedek. Die snit N—L—K gee die volgende te sien: Aan die kant van N vertoon die spruitwal 'n kalkbank van 5 voet dikte, waarop 'n laag kalksand lê van 1 voet dikte, waarop weer 3 voet sand lê. Hier is op die kalksand enige Koningse werktuie gekry. Aan die oostelike wal van die spruit egter kom oor 'n groot uitgestrektheid leisteen aan die dag, wat weer bedek word deur 'n taamlik dik laag kalkgruis. Dit is 'n gruisryke laag waarin die klippe verkalk is. Hierdie kalkgruis is weer bedek deur sand. By L, die hoogste punt van hierdie gedeelte, lê 'n sandbank van 4 voet dikte. Daaronder lê 'n gruisbank, wat rondom die hele knop aan die dag kom en die grootste gedeelte van die veld tussen L en M bedek. Onder die gruis lê op die oostelike helling omtrent 3 voet kalksand en daaronder miskien 2 voet kalk, wat weer op 'n laag van 6 voet dikte van kalksand en potklei lê. In hierdie onderste laag kom ook enkele kalkgedeeltes voor. Aan die oostelike kant van die oostelike spruit kom alleen leisteen aan die dag. Die oppervlakte is hier bedek met talryke klippe, waartussen baie werktuie van die Koningse Industrie en die Mosselbaaise Kultuur aangetref is. Op die gruisveld rond L en na M toe is honderde fraai werktuie van die Koningse Industrie versamel. Hier was geen Mosselbaaise werktuie nie. Wel is op hierdie veld twee werktuie gevind, wat geen handpikke is nie maar wat enigsins lyk op ovaalvormige handpikke en altans 'n dergelike tegniek vertoon; hulle lyk ook 'n bietjie op die skyfvormige werktuie van die Mosselbaaise Kultuur wat ek beskryf het in (6). Ek twyfel geen oomblik daaraan nie, dat hierdie werktuie op toevallige wyse op die gruisveld geraak het vanaf die oop leisteen gedeelte onderkant M. Op die leisteen by M is naamlik 'n groot aantal werktuie van ouere kulture gevind. Ons besit van hier 'n aantal Pnielse byle van diabaas en 'n groot aantal klein handpikke van lidianiet. Die handpikke is hier alleen van lidianiet gemaak, nie van ander materiaal nie. Hier lê ook werktuie van die Mosselbaaise Kultuur en van die Koningse Industrie. Die Koningse werktuie kan hier oorspronklik agtergelaat wees, maar hulle kan ook van bo, van die gruislaag rond M, afkomstig wees.

Die oop leisteen langs die spruit by M loop suid van die pad na die Kalkfonteindam nog 'n end deur. Die snit deur punt P toon dat dit in 'n diepte lê langs die spruit, wat die indruk gee of dit 'n ou loop van die spruit is. Ook hier is Pnielse byle, klein handpikke, Mosselbaaise en Koningse werktuie gevind. Ek moet hier nog wys op die eienaardigheid van die formasies by L. Aan die westekant lê tussen vaste gesteente en sand net 'n kalkgruisbank. Aan die oostekant lê die opeenvolging kalksand (met potklei en kalk)—kalk—kalksand—gruis. Blykbaar kom die kalkgruis van die een kant ooreen met die kalk van die ander kant. Maar hier het ons kalk wat op kalksand lê en weer deur kalksand bedek word. As die opeenvolging by B, D, F, H en N deur 'n geleidelik droeër wordende klimaat moet verklaar word, dan sou die opeenvolging oos van L 'n skommeling in die

klimaat voorstel, wat by die ander punte geen invloed gehad het nie. Dit is natuurlik ongegrond. Die verkalking en versanding is geen bewys nie vir 'n voortskrydende uitdroging soos blykbaar aan ons voorgehou word (bl. 66). Verkalking is slegs 'n bewys van 'n droë klimaat en veranderinge in die verkalking is van plaaslike aard.

By punt P lê aan die westekant 2 voet sand op omtrent 4 voet kalksand. Aan die oostekant egter, lê daar 2 voet sand op 4 voet kalk. 'n Snit oor O, wat baie naby P lê, toon al weer verandering. Hier lê by Q net as by P 2 voet sand op 4 voet kalksand en die spruitwal by O gee dieselfde lae te sien. Hier is die kalklaag oos van P dus weer 'n kalksand. Maar 'n bietjie verder van die spruit by O net oor die sandknop, is hierdie kalksand in 'n braklaagte al weer verander tot kalk. Maar aan die oostelike rand van hierdie braklaagte lê op hierdie kalk weer 'n dun laag kalksand en daarop weer 'n laag kalk. In hierdie brak is duidelik te sien, dat die verkalking die gevolg is van plaaslike infiltrasie van onderaf. 'n Snit van O in die rigting van S sal dit verduidelik. Hier lê by O sand op kalksand, dan kom 'n waaiervormige kalkliggaam met sand bedek en daarnaas lê 'n kalkbank wat na S toe verdwyn. Daarop lê 'n kalksand met gruis, wat na S toe skoon kalksand word en daarop lê dan agtereenvolgens opmekaar sand—kalk—sand. By punt S lê 2 voet sand op 4 voet kalk, maar by R, regoor die spruit by S, is die opeenvolging van onder na bo: 2 voet gruis, 3 voet kalksand, 3 voet sand. By O en R is in die braklaagte baie pragtige werktuie van die Koningse Industrie versamel. By O lê hulle op die kalksand tussen die twee kalklae en ook gedeeltelik op die kalk. By R lê hulle in die kalksand onder die sand.

Tussen T en X loop die spruit tussen steil en hoog walle. Die formasie aan altwee kante is dieselfde, n.l. 'n dik kalkbank van miskien 8 voet dikte, daarop 'n laag sand van 4 voet dikte en daarop 2 voet growwe gruis. Merkwaardig is, dat die growwe gruis talryke klein handpikke bevat en groot skilfers. In die spruitbed het ook enkele van hierdie werktuie gelê. Totsover het ons nêrens so 'n growwe gruis op sand of kalksand aangetref en seker geen handpikke nie. Waarom lê hierdie gruis dus so hoog bo die bed? Die verklaring hou verband met 'n dooie arm van die spruit aan sy westekant. Van naby die punt X loop daar naamlik 'n droë spruitbed onder 'n hoek van 'n 45 grade van die teenswoordige bed weg en virby die punt U loop dit weer daarin. Hier egter is dit die ou loop wat die rigting aangee, want die nuwe bed loop onder 'n groot hoek in die oue. By die begin lê die bodem van die ou bed omtrent 8 voet bo die bodem van die spruit. Die diepte van die ou bed self onder die oppervlakte is maar 3 of 4 voet. Die bodem bestaan eers uit sand met growwe gruis, veral werktuie, naby sy end word dit leisteen. Hier het die dooie arm oor sy laaste honderd voet 'n verval van omtrent 10 voet. Hier staan die bed dus steil, terwyl die eerste gedeelte byna horisontaal is. Die nuwe spruitbed is bedek met sand maar

in sy eerste helfte met groot rotsblokke van diabaas. Naby punt V gaan 'n diabaasgang dwars deur die spruitbed. Hierdie diabaas kom omtrent twintig treë van die oostelike spruitwal af in die veld aan die dag. Verder na die suide is die spruitbed heeltemaal skoon en bestaan dit uit leisteen. By die begin van die ou spruitbed is daar 'n platform van kalk of kalksand aan die oostelike kant in die nuwe spruitbed. Die platform lê op 3 of 4 voet bo die nuwe spruitbed. Hierdie platform lê omtrent 5 voet onder die begin van die ou loop. Dit lyk asof hierdie platform ook 'n stuk is van die ou loop van die spruit. Die verskil in hoogte is nie 'n besondere beswaar nie. Omtrent 100 treë stroomop lê die bed van die spruit net so hoog as die begin van die ou loop. Wat die afsettinge betref is daar naby die noordelike end van die nuwe loop soms drie growwe gruislae in die kalk. In die midde word kalk en sand deur 'n skerp en vry reguit lyn geskei; blykbaar is hier 'n diskonformiteit. Aan die begin van die dooie loop lê 'n bank van growwe gruis met werktuie dwars oor die bed, wat die loop heeltemal afsluit. Hoe moet dit alles nou verklaar word? Eers is blykbaar die spruitbed langsamerhand meer en meer versand en verkalk. Die spruit het meanders geslinger deur sy afsetting en het die reeds verkalkte afsettinge weer afgeskuur. Langs sy walle het die ou spruit altyd meer sand opgehoop. So is die ou loop bereik wat nou nog bestaan. Die ou spruit kon moeilik verder na die weste toe uitbuig omdat hier 'n hoogte lê van leisteen. Die uiterste is bereik in die ou loop, waar die bed op die leisteen sterk hel in die rigting van die nuwe spruit. By verdere aanvoer van sand was daar geen geleentheid meer nie vir die spruit om uit te wyk as dit aan die binnekant van die buiging afgesit word, soos altyd gebeur. Byna algehele versanding was die gevolg. Toe is daar gebeur wat vroeër in geringere mate al twee of drie keer in die kalkafsetting en daarna drie keer in die sandafsetting gebeur het. 'n Reeks flinke storms het die ou spruit soveel water besorg dat dit met geweld die boonste gedeelte van sy loop skoongespoel en die gruis afgesit het waar die verval gering was, dit is tussen die punte U en Z waar die bed byna horisontaal was. Hier het dit by die buiging by X oorstromings besorg, sodat die gruis daar op die veld afgesit is. Maar daardeur het die water 'n meer reguit koers gevolg en naby T oor die steil wal van die ou loop gestort. Daardeur het die ou loop minder water gekry en is sy inloop ook met gruis toegegooi. Of hierdie stormvloed nog herhaal is kan nie gesê word nie. Wel is seker, dat toe eenmaal die water die rigting X—T geneem het, die sandige ondergrond baie gou uitgeskuur was. So het die teenswoordige loop ontstaan. Dat hierdie verklaring waarskynlik is, blyk uit die feit, dat die spruitbed wel 'n hele end skoon is bokant Z maar dat in die omgewing van die punt AA die westelike wal van die spruit met dieselfde gruis bedek is as wat by T—X voorkom. 'n Snit by 1—2 toon dat hier die spruitbed uitgeskuur is in lei, wat aan die kante bedek word deur kalksand. Teen die lei- en kalksand-wand van die spruitbed lê hier 'n growwe gruislaag. Hierdie growwe gruis

is 'n oorblyfsel van die growwe gruis wat eens op 'n tyd die hele spruitbed hier bedek het. Die gruis wat hier weggespoel is lê nou tussen die punte X en T bo die dik versanding met kalk. Die gruislaag by 1—2 bevat ook klein handpikke en groot skilfers. Ons het hier dus die eienaardige geval dat gruis, wat op een plek in die spruitbed lê, op 'n ander plek en selfs nie ver weg nie, hoog bo die spruitbed gevind word. Hier is langs die spruit 'n terras gevorm waarvan die gruis ewe oud is as die van die spruitbed. Die geval is daarom so treffend omdat die gruis in die nuwe bed tussen X en T dieselfde werktuie bevat as die wat bo die wal lê. Hieruit kan gesien word dat die sogenaamde gruisterrasse by Riverview aan die Vaalrivier, waar die rivier 'n lang tydperk van meanders deurgemaak het tengevolge van barrières en verstopping geen argeologiese of stratigrafiese waarde het nie.

Waarvandaan kom hierdie growwe gruis met werktuie in die spruit van Brakfontein? Daar is tot sover geen lidianiet rondom die spruit gevind nie. Het die primitiewe mens die klippe na die spruit gedra? Die antwoord op hierdie vrae lê 'n bietjie verder stroomop. Vanaf die punt AB is die spruit al baie vlak. Langs die kante lê brakgronde. Op die brak (kalksand) lê vanaf AD tot by die hek van die huis op Valsfontein talryke werktuie van die Koningse Industrie. Hier en daar work ook 'n klein handpik gevind of klippe wat tot die gruis van die handpikke behoort. Tussen die punte AB en AD kom daar van die oostekant 'n klein lopie in die spruit. Die lopie kom van die berghelling, wat hier baie nader by die spruit is as by enige ander gedeelte wat ons tot sover bespreek het. Na die suide toe kom berghelling en spruit nog nader bymekaar en op Brakfontein loop die spruit baie naby aan die voet van die helling. Die genoemde lopie is maar klein, so klein, dat dit nie eers 'n vaste bed het nie. Met elke groot reent loop die water van die berg af en maak gebruik van hierdie lopie. Klippe word dan endjies saamgespoel en so het dit gebeur dat hierdie lopie al 'n hele waaier van los klippe neergelê het. Daar is hele plate van hierdie klippe en by die lopie lê walle daarvan van 'n paar voet dik. Die waaier van klippe strek hom uit tot by die groot spruit en sonder twyfel sal elke groot reent 'n aantal klippe in die spruit afspoel. Hierdie klippe is nou prakties almal stukke lidianiet en die hoeveelheid groot skilfers, wat daaronder is, is verbasend. Ook handpikke van die soort wat oorals langs hierdie spruit lê, is hier gekry. Die bewerkte klippe wat hier lê verskil in geen enkel opsig van die wat b.v. tussen T en X gevind is nie, behalwe dat hulle rooi en die klippe wat 'n tydlang in die spruit was, blou is. Dit is duidelik dat die oorsprong van die gruis met handpikke, wat laer af in die spruit lê, hier moet gesoek word.

Die werktuie wat nie tot die Koningse Industrie behoort nie en wat met Koningse werktuie in hierdie omgewing saam gevind word en wat in vorm en bewerking ooreenkom met werktuie uit die klippewaaier van die lopie moet verklaar word as van die waaier afkomstig. Deur die nabyheid van die berghelling word werktuie van allerlei kulture geleidelik laer en laer gespoel oor werkplekke van ander kulture en die gevolg is 'n mengelmoes.

Behalwe werktuie van die Koningse Industrie lê daar op die brak by die hek ook werktuie van die Mosselbaaise Kultuur. Oos van die fontein lê 'n brakveld met talryke werktuie van die Koningse Industrie en enkele van die Smithfieldse Industrie. Ook lê hier Mosselbaaise werktuie. Handpikke het ek hier nie gevind nie, maar daarby wil ek op merk, dat hier nie op die voet van die berghelling gesoek is nie. Verder na die Suide lê die plaas Brakfontein. Die diep spruit met dik kalkbanke begint eintlik by die fontein. Verder suid is die spruit weergegee in die kaart van fig. 2. Dit is hier feitlik 'n onaansienlike lopie, wat op enkele plekke walle het van 4 voet hoogte. Die sigbare kalk is hier omtrent 2 voet dik en hierop lê 2 voet kalksand. Dit word weer bedek deur waaisand. Die wande by die fontein bestaan uit 5—6 voet sand, waarop 3—4 voet kalk, wat weer deur 'n paar voet kalksand bedek is.

Op Brakfontein (fig. 2) lê daar suidoos van die spruit 'n uitgestrekte veld rooi kalksand, met waaisand en bossies bedek. Dit loop tot teen die berghelling. Op die oop gedeeltes tussen die sandknoppe lê talryke werktuie van die Koningse Industrie en van die Mosselbaaise Kultuur. Handpikke is hier nie gevind nie. Was hulle hier al opgetel? Teen die berghelling egter het ons op een plek in een van die klein lopies 'n Pnielse byl gevind en op 'n ander plek, ook in die klein lopie, 'n Stellenbosche handpik. Die berghelling is bedek met skilfers van lidianiet en bo op die rand kom lidianiet in groot blokke aan die dag. Hier is groot skilfers talryk; handpikke is hier nie gevind nie. Blykbaar het ons hier dieselfde toestand as by die genoemde oostelike lopie. Ook hier vind die bedekking plaas van jongere kulture langs die spruit deur ouere wat op die berghelling lê.

Die " Fauresmith II " kultuur deur van Riet Lowe beskrywe van hierdie " tipe-vindplek " is 'n mengsel van werktuie van die Koningse Industrie, die Mosselbaaise Kultuur, die Pnielse Kultuur en miskien nog ander kulture.

Enkele feite wil ek nog in besonder belig. Talryke plekke is aangetref waar die Koningse Industrie suiwer voorkom. Op een plek, by die huis op Valsfontein kom werktuie van die Smithfieldse Industrie voor. Dit wys op 'n duidelike skeiding tussen die twee onderling en ten opsigte van ander kulture. Oos

van die groot spruit by punte E, G en K kom Mosselbaaise en Koningse werktuie deurmekaar voor. Hier lê egter geen handpikke nie en derhalwe kan die lang skilfers nie in een kultuur saamgevoeg word met die handpikke nie, soos in "Fauresmith II" gedoen word. Dan is daar die feit, dat waar die handpikke gevind word altyd Pnielse byle aanwesig is. Dit is die geval by punt M, tussen punte T en X, by die lopie tussen AB en AD en op Brakfontein waar van Riet Lowe hulle versamel het. As die twee werktuigtipes in verskillende tyde ontstaan is, gee 'n verklaring van hierdie feit groot moeilikhede. Is die twee werktuigtipies egter in dieselfde tyd ontstaan, dan spreek hulle gesamentlike voorkome op een plek vanself; maar dan sou hulle behoort tot die tyd van die Pnielse Kultuur. Dit is tenminste die Pnielse byl wat dadelik as sodanig herkenbaar is. Maar ons is gewend om by Pnielse byle altyd grotere handpikke te vind. Hoe moet die kleinere handpikke dan verklaar word? Nou is dit 'n feit dat op ander vindplekke byle sowel as handpikke gemaak is van 'n fynkorrelige diabaas of van kwartsiet. Dat die byl hiervan gemaak kan word en selfs van growwere gesteentes lê voor die hand, omdat hy met 'n paar groot slae en enige kleintjies klaar gevorm is. Maar met die handpik is dit anders. Hier moet talryke klein slaggies 'n groot aantal skilfers verwyder om 'n goed gevormde werktuig te maak. Daarvoor is growwe gesteentes minder geskik en dus fynere gesteentes 'n vereiste. Boondien is daar vir die vorming van die punt deur herhaalde slae 'n taai gesteente nodig, 'n taaiheid wat growwe diabase nie besit nie. Nou is dit ook 'n feit, dat daar rond Brakfontein, Valsfontein, ens., net twee gesteentes is waar werktuie van gemaak kan word: Diabaas en lidianiet; kwartsiet is daar nie. Vir handpikke is die diabaas minder geskik en dus was daar vir die mens uit die Pnielse Tyd wat handpikke wou maak in hierdie streek net een materiaal beskikbaar waarvan dit kon gedoen word: Lidianiet. Dit was nog dieselfde mense wat elders groot handpikke van ander materiaal gemaak het. Hulle het dus nog presies dieselfde tegniek toegepas. Van Riet Lowe (1, bl. 90) sê daaroor onder die hoof "Fauresmith I," dat onafgewerkte handpikke van kerne gemaak, dikwels nie te onderskei is nie van "vroeg-Stellenbosch" en "Chelliese" vorme. Hy noem die tegniek tipies Abbevillies. Die enigste verskil tussen die handpikke van lidianiet en die van diabaas en kwartsiet is dus dat hulle kleiner is as die laaste. Ek meen, dat dit in hierdie geval aan die materiaal toegeskryf moet word. Daar is dan geen rede nie om die handpikke in 'n ander tyd te plaas as die Pnielse byle. Dit behoef dan nie noodwendig dieselfde kultuur te wees nie; dit kan twee gelyktydige kulture gewees het van twee beskawinge wat naas mekaar voorgekom het.

Wat die kulture betref kom ek tot die volgende samevatting: Dit is nie onwaarskynlik nie, dat daar in Suid-Afrika, net soos in Europa, twee beskawinge gewees het, waarvan die een gekenmerk word deur werktuie wat op kerne gemaak is en die ander deur werktuie wat van skilfers vervaardig is. As dit so is, sou

die opeenvolging van die Suid-Afrikaanse kulture as volg in tabelvorm kan opgestel word:

Kernklip-beskawing.	Skilferklip-beskawing.	
		Wiltonse-Industrie.
	Koningse Kultuur	Smithfieldse-Industrie.
		Koningse-Industrie.
	Mosselbaaise Kultuur.	
" Fauresmithse " Handpikke.	Pnielse Kultuur.	
Vaalse Kultuur.		
Stellenbosche Kultuur.		

As daar geen twee beskawinge was nie behoort die ,, Fauresmithse " handpikke tot die Pnielse Kultuur. Is daar wel twee dan sal die laaste fase van die kernklipbeskawing 'n aparte naam moet kry; Fauresmith sal waarskynlik verwarring veroorsaak waar die naam reeds herhaaldelik vir verskillende mengelmoese gebruik is. As eerste redmiddel stel ek voor om die bepaalde handpikke as tipe van die kultuur te beskou, dan weet ons waaroor ons praat.

Wat die klimate van die Steentydperk betref kan ek nie met die geologies-argeologiese ondersoek van die Vaalrivier saamstem nie. Hiervóór is reeds 'n paar pertinente vrae gestel. As hulle bevredigend kan beantwoord word, is daar miskien rede om my opvatting te wysig. Tot solank is my opvatting hieroor die volgende: Voor die begin van die Steentydperk was daar in Suid-Afrika 'n groot reentyd. Daardeur is die valleie van die Vaalrivier en sy syriviere gevorm. Die reenval het geleidelik verminder en growwe gruis is afgeset op die bed van al die riviere. Toe het die mens op die toneel verskyn en hy het van gruis in die rivierbedde en van klippe aan die berghellinge werktuie gemaak. Die toestand het aangehou gedurende die gehele Oudste Steentydperk, maar met 'n geleidelike vermindering van reenval. By die begin van die Mosselbaaise Kultuur was die reenval so gering dat die riviere geen gruis meer kon vervoer nie. Toe het versanding begin. Dit het minstens aangehou tot na die einde van die Mosselbaaise Tyd. Die Koningse Industrie lê ook hier en daar onder die oppervlakte. Die Smithfieldse en Wiltonse Industrieë lê in en op die boonste sand. Dit lyk of daar geen verdere vergroting van die sandafsetting plaasvind nie en of die riviere die normale toeloop weer kan opruim. Van 'n

sterkere reenval hierna is daar nog geen bewyse nie, want die syriviere van die Vaal loop nog op 'n dik sandbed. Die Vaal se bed in engere sin is nie versand nie, omdat die syriviere genoeg water aangebring het om dit skoon te hou. Ek sien dus slegs een klimatologiese siklus, wat nog nie voltooi is nie. 'n Reentyd gevolg deur 'n langsaam droër wordende tyd, wat miskien vandag nie droër word nie.

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UITLEG VAN TEKSFIGURE.

Fig. 1.—Kaart van 'n deel van die spruit, wat van Brakfontein oor Valsfontein, Telegraafsfontein en Goede Hoop na Rietrivier loop. Skaal 1 dm. = 300 vt. × ⅓. Ko = Koningse Industrie. Mo = Mosselbaaise Kultuur. Pn. = Pnielse Kultuur. Sm. = Smithfieldse Industrie.

Fig. 2.—Kaart van die deel van die plaas Brakfontein, wat tussen Valsfontein, die pad Koffiefontein-Fauresmith en die rande suid en oos daarvan lê. Skaal 1 dm. = 300 vt. × ⅓. Tussen die spruit en die berghelling lê 'n veld van rooi kalksand wat met knoppe rooi sand bedek is. Die veld is met 'n gebroke lyn van lang strepies omlyn. Tekens as vorige figuur.

Die snit is getrek van die rand dwars oor die veld na die lopie en pad. Dit is alleen 'n skets en nie op 'n bepaalde skaal geteken nie.

Fig. 3.—Snitte oor fig. 1. Die skaal van die snitte oor C-D, O-S, P, O-Q, R-S en T-U is: Lengte 1 dm. = 300 vt. Hoogte ½ dm. = 10 vt. Die ander snitte oor die letters was op dieselfde skaal geteken, maar die blokmaker het die tekeninge verklein.

Fig. 4.—Die lengte van snitte A-B, E-F, T-H en K-L-N was respektiewelik 3 dm., 4½ dm., 5 en 7 sestiende dm., 7 en 1 agste dm.
Die snit oor 1-2 is 'n skets.

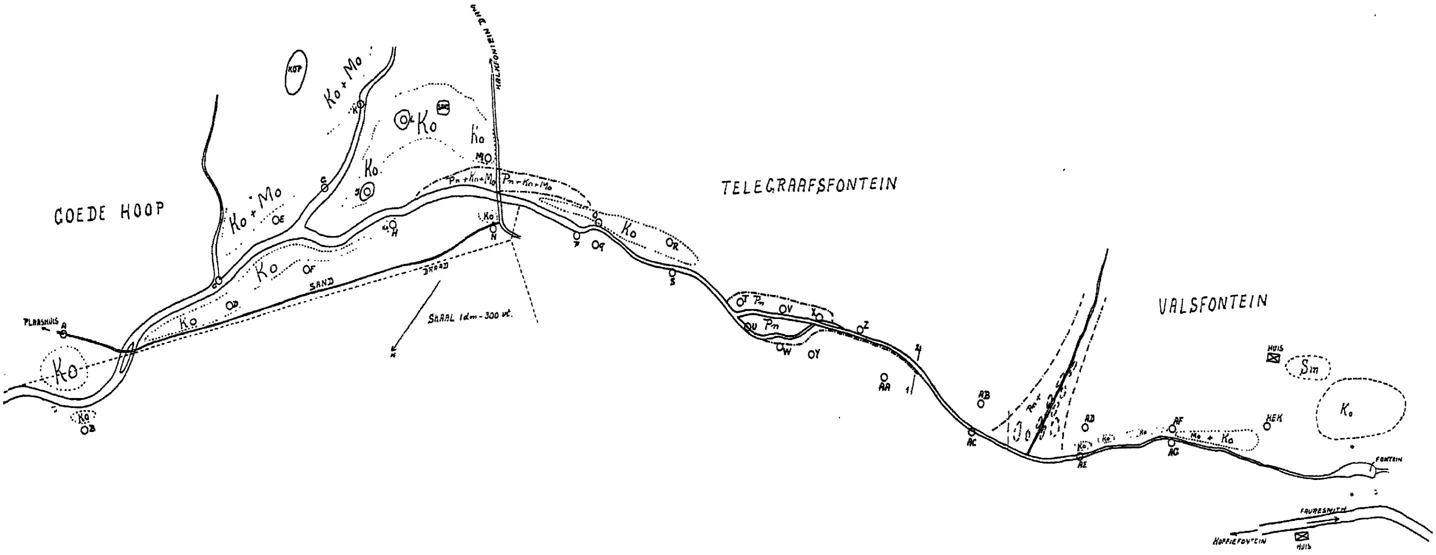

Fig. 1.

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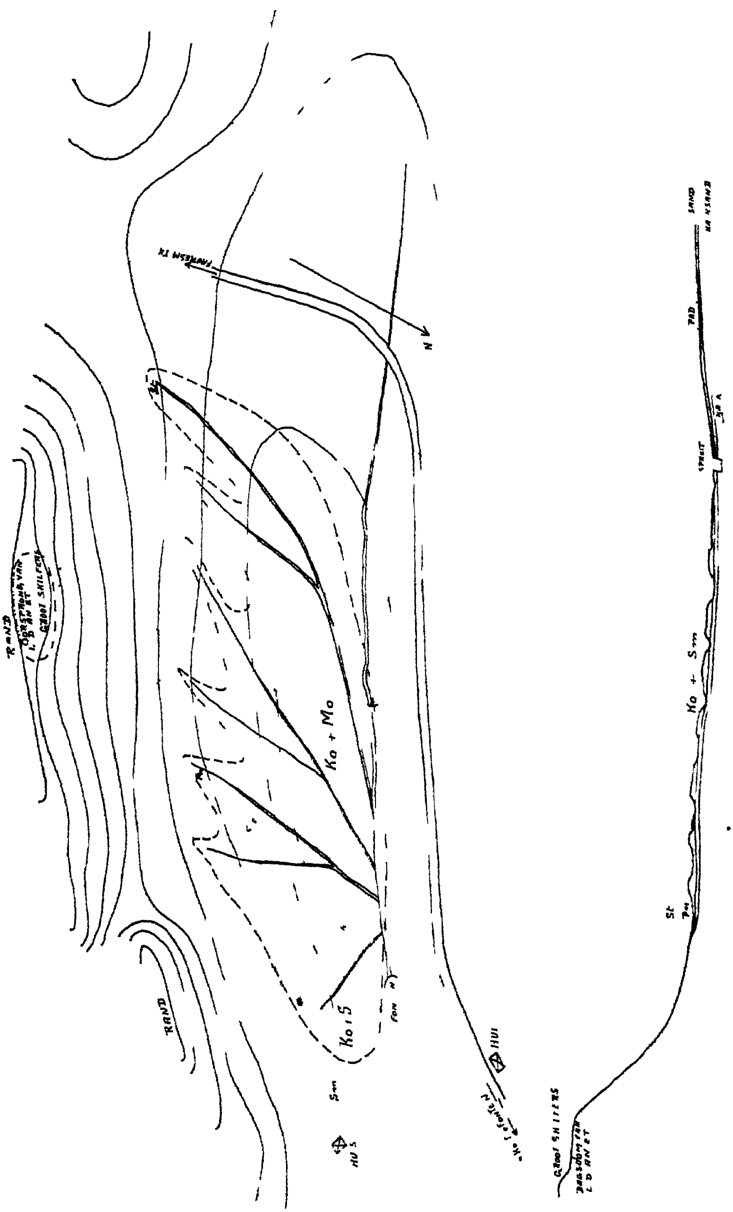

Fig 2

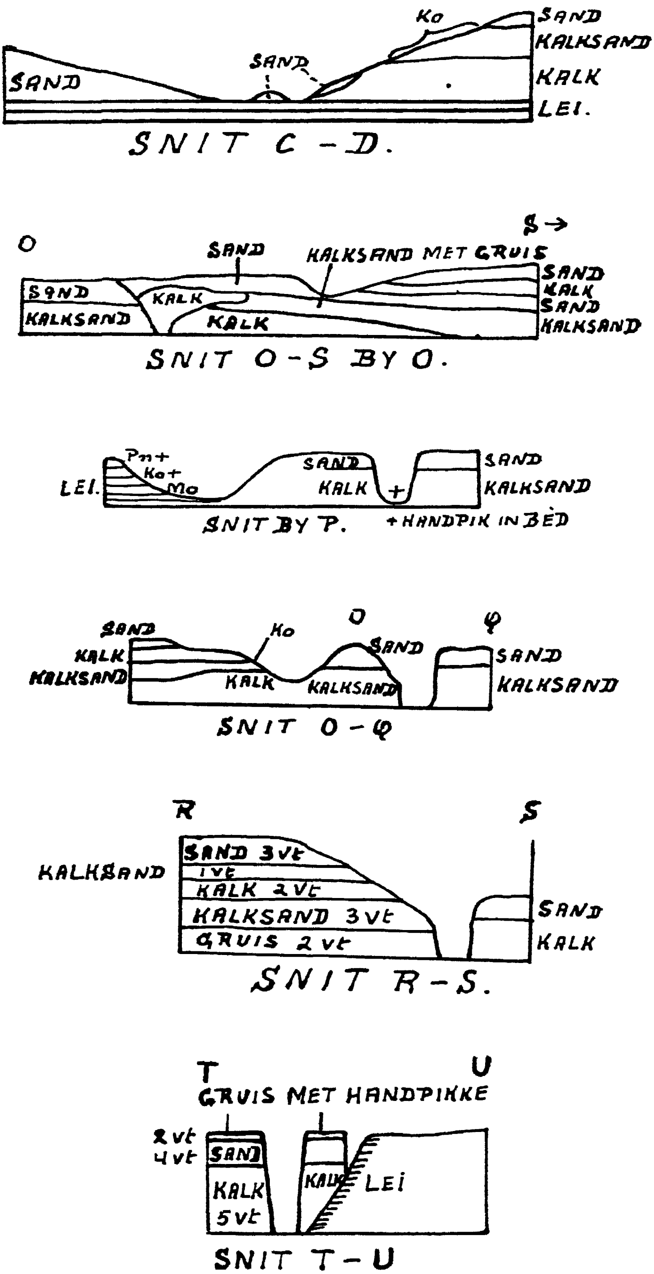
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Fig. 3.

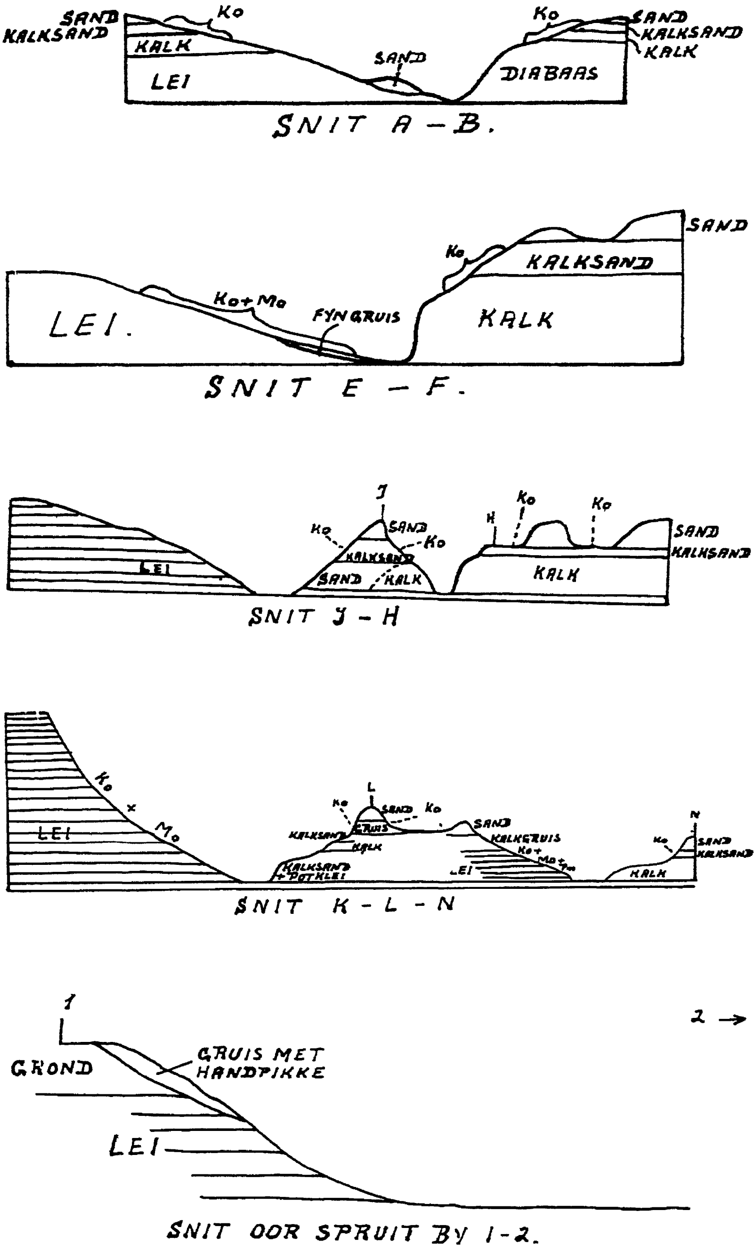
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Fig. 4.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol XXXV, pp. 126-153, December, 1938.*

WHITHER MATRIC?

BY

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One of the demands of modern society is that practices affecting the lives of human beings should be based on scientific principles. We expect this from medicine and public health. We expect it from engineering. We expect it from industry and agriculture. I think we can legitimately expect it from education and other methods of social control.

My original intention was to avail myself of this occasion to give you in my Presidential Address a general survey of the position of social research in the Union, pointing to the need for such research, its organisation, finance and special difficulties in South Africa. As I have, however, been asked to read a paper on this very topic at the Inaugural Meeting of the National Research Council and Board which also takes place this month, I have decided rather to take for this address *one* specific problem and deal with it more or less thoroughly. Perhaps it is as well, for I think it is better at such a meeting as this to " get down to brass tacks " than to deal in generalities.

My object in this paper is to make a plea for the application of scientific principles and techniques in a field which touches the youth of our country most intimately—I mean the field of examinations, and in particular the Matriculation examination which exercises probably a greater influence on education in this country than any other institution.

Such an investigation will involve not merely a study of technique such as forms of tests and statistical treatment of results but also a consideration of the purposes of examinations. The problem involves the question of social justice in the distribution of education for the development of individual talent, the question of the selection and maintenance of an *élite*, and the question of the concept of culture. In short, the problems are philosophical and social as well as administrative and technical.

In considering examinations there are two criteria which can be applied viz. (a) validity and (b) reliability.

Validity, may be defined as *the degree to which an examination measures what it intends to measure.*

Reliability on the other hand is *the degree to which the scores or marks obtained in an examination at one time agree with scores or marks made by the same pupils in a similar or equivalent examination at another time.*

Let us consider these two criteria with regard to the Matriculation examination.

(a) VALIDITY.

This is the more difficult of the two criteria to apply, because it involves the question of the *purpose* of the matriculation examination. What does the examination really purport to measure? It is very difficult to say.

As popularly conceived it seems to serve two purposes: 1. It is regarded as *a stock-taking examination* indicating what has been learnt. 2. It is supposed to provide a *prognosis* of what a young person can still learn. It is an instrument for selecting our intellectual elite, i.e., those who can go to university.

Matriculation as a Stock-taking Examination.

Let us consider the first purpose. Rightly or wrongly the matriculation certificate is regarded as a guarantee of a certain definite scholastic attainment. This assumption seems to become less and less commonly justified, and we note in recent years a tendency for business concerns, e.g., the banks, and for the public service, not blindly to accept the matriculation qualification, but to institute their own examinations. I think this tendency is all to the good. They are at any rate examinations which cannot be crammed for. This tendency seems to imply tacitly a criticism which Professor C. Delisle Burns expressed as follows (at the first International Conference on Examinations held at Eastbourne, 1931.): "One of the worst troubles in the whole examination system is that it has been devised by professors, and the best thing that professors can think of is themselves; they therefore test candidates by what are tests of competence for professors, but not for bankers and other persons."

When visiting Australia last year I found a rather similar instance of this. This is how Professor Hancock of Australia describes it: "The Australian Government insists," he says, "generally upon the rule that everybody must enter the public service at the age of sixteen or thereabouts. At the same time, by means of an excellent system of scholarships, they cunningly entice the cleverest boys to the Universities. When they have been enticed thither, these boys discover (unless they have entered upon a strictly technical training) that there is nothing for them to do except teach. So they return to school and encourage other clever boys to win scholarships. In this way the State has most ingeniously contrived that its system of democratic education shall not embarrass the public services by introducing into them resplendent talents. (There has, it is true, been con-

siderable reform in recent years). While democratic sentiment applauds the sound argument that every office boy should have a chance to become a manager, we often find it perverted into a rule that no one shall become a manager who has not been an office boy."

In spite of the fact that university professors, as a rule, are the examiners for matriculation, one finds that they too sometimes complain about the lack of scholarship amongst those who enter university. Is this merely a general trait of human nature manifesting itself in education ? Or is there real truth behind it ? It is difficult to say, because we find as often that the high schools complain about the poor preparation of the primary school and so on down all the standards to the kindergarten. This is what one might call *the law of retrospective recrimination in education*. Very little light on our subject, therefore, can be expected from such reactions.

What is needed is scientific investigation of the relationship between high school and university. In this connection I would like to mention two recent studies. The one is the " Study of the Relations of Secondary and Higher Education in Pennsylvania,"* which is probably one of the most valuable scientific contributions to education made in modern times. This Study derives its significance from the fact that continuous records of ability and achievement have been secured and maintained by the same body for a large group of students (about 28,000) from their entrance into high school until their graduation from university, i.e., over a period of eight years. Hundreds of high schools and forty colleges were involved. The plan of the inquiry was to subject the educational procedure of secondary schools and colleges as a unit to examination at three points: (1) at the time of entrance to the secondary school, (2) at the close of the secondary school course, and (3) towards the close of the college course. The instruments of measurement used were intelligence tests, " new type " examinations and the cumulative record card.

The Study, in other words, was intended to secure as much information as possible about the scholastic and other progress of students from the last years of the elementary schools, through the secondary schools, and in the colleges up to the time of graduation. It would thus follow the progress of students through their educational careers and close with an assessment of the final product or " an inventory of the baccalaureate mind." In this way it was hoped to discover as much information as possible about a whole school and college generation, and to answer some of the following questions: What sort of mind goes to university, colleges, teachers' colleges, business, industry, etc.? How many students with marked aptitude for intellectual pursuits are unable to go to college for economic or other reasons, and what propor-

* Published in *The Student and his Knowledge*: Bulletin No. 29. The Carnegie Foundation for the Advancement of Teaching, N.Y. (1939).

tion actually enters college without evident qualifications? What sort of mind goes to college, continues and grows in knowledge and power.

The tests revealed the most amazing variability between institutions, among students taking the same courses in each institution and in each institution among students taking different courses such as arts, science, business, education and engineering. Further, there was a considerable amount of overlapping among high school seniors, second year university students and final year B.A.s. A percentage of the last mentioned was found to rank lower than a percentage of the high school seniors. A system such as this, it was concluded, is defective in a large number of ways, but primarily in attempting to deal with bodies of students as homogeneous when in fact they are highly heterogeneous, and, on the specious plea for equality, undertaking to provide for them varieties of courses and curricula which are assumed to be equivalent.

It is impossible for me here to give any further details. A fairly full summary is given in Kandel's: *Examinations and their Substitutes*, p. 133, 1936. The main general conclusions arrived at were as follows:

(1) Learning students is a pre-requisite to teaching them, or to use a phrase which is now frequently used, education must be individualised.

(2) Education must be regarded as a continuous process and must be based upon all kinds of information that can be cumulatively recorded about a student.

(3) The abilities and capacities of students must be identified as early as possible and more adequate provision must be made for differentiated treatment of students in the assignment of programmes of study. And

(4) An integrated education demands early identification of needs, closer co-operation among teachers at different levels of education, and more co-ordinated procedures, all of which can be made effective through the use of cumulative record cards which follow a student through his educational career.

The other study was undertaken by the Scottish Committee of the International Examinations Enquiry. It consists of two parts, the one prospective, the other retrospective. The first was part of the larger survey, "*The Intelligence of Scottish Children*": A National Survey of an Age Group 1933, under which 87,498 children were mentally tested. Out of these 1,000 were selected as a representative group and they are being studied intensively as they progress through school and later.

The second, viz., the retrospective enquiry, undertook to investigate the prognostic or predictive value of the examination for entrance to the university. The group investigated consisted of 472 students, men and women, who had entered one of the

universities in 1928. The results of this study have been published under the title: "*The Prognostic Value of University Entrance Exams in Scotland.*"

Evidence of the interest in the two Scottish studies is indicated in the co-operation of every education authority and private school, the central authority, and the university. It is hoped through these channels to influence public opinion on the one hand and to see that no pupil of ability fails to receive the education appropriate to him.

One only wishes that such studies were possible in South Africa. They, more than anything else we can do, will throw light on the vexed matriculation problem, and incidentally be conducive to a more enlightened public opinion about it. We need less heat and more light on this subject.

The little evidence there is seems to point to the need. I quote one instance for what it is worth.

A few years ago, 259 physically fit young men presented themselves as entrants for the police. The minimum educational qualification required was Standard VI. There were, however, quite a number of Junior Certificate candidates and matriculants amongst them. Before being admitted they had to take a simple scholastic test of about Standard VI level in Arithmetic, English and Afrikaans dictation and translation into and from English. Only 44 (i.e., 17 per cent.) passed. Amongst the 215 who failed there was a surprising proportion who held Junior Certificates or Matriculation Certificates. I do not for a moment wish to suggest that the matriculants who failed are representative products of the high schools. On the contrary. The point is that in their case at least the mere fact that they had passed the examination was no absolute guarantee of their having reached that level of scholarship usually associated with the matriculation certificate. As I said before, however, the evidence on this score (i.e., whether the matriculation examination is an efficient stock-taking measure) is so slight as not to warrant any very definite conclusion for or against its validity.

Matriculation as a Prognosis of University Success.

Coming, however, to the other purpose of the matriculation examination, namely, *the selection of those who are fit to enter university*, we have a little more definite information regarding its validity, i.e., whether it is an effective instrument for selecting pupils for university study.

About two years ago I made a study of the school and university careers of over 8,000 students who entered our university institutions during the six years 1930-35. All these students had matriculated, having passed in the required combination of subjects which is supposed to render them fit for university study. Yet I found that *out of the 7,080 of those students who went direct from school to university, 3,185 had failed in their first year at university*. That is, in respect of nearly

half of the cases the matriculation examination was a poor prognosis of university success. This does not say much for the validity of the matriculation examination. In fact, with a 50-50 chance of success in prognosis, it is a pretty poor gamble. 1,744 i.e., about 25 per cent. of these students had failed in two or more subjects. Remember, this is not a mere freak result of one year but these findings are based on the average over six years of university students. To say the least the situation is shocking, particularly if one considers the human wastage involved —not to mention parents' money.

What makes it worse is that the matriculation curriculum devised for university entrance dominates the schools from which the majority of pupils do not enter university. Taking the school as a whole, only about three out of every 100 children who enter school go to university, and the school careers of the 97 per cent. are directly and indirectly dominated by the requirements of the 3.

Let me explain how this actually works out.

Taking the average *per year* over the 5 year period 1930-1934, I found that there were in the Union about 6,500 pupils in Standard X out of which about 5,000 ultimately passed the matriculation, senior or school-leaving certificate examinations. Out of these matriculants 1,600 entered university, i.e., one-third.

The majority of secondary and high schools are small, and not a very wide selection of subjects is possible. Hence the schools play safe and confine themselves to the course required for university entrance, irrespective of the needs of individual pupils,lest the few (usually the local minister's or doctor's child) who aspire to university study be penalised. This is what I have called the *determinism of distance* which regulates the secondary education of such a large number of children in this sparsely populated country of ours and chases them *nolens volens* up the narrow matriculation path leading to the university. The veritable feast of 37 possible subjects to be found in the matriculation syllabus is possible only *in theory* to the many, and *in fact* only to the few, i.e., to the children in the large urban centres, where the schools are larger and there is also a choice of school.

But to return to the matriculation examination, one may mention two likely causes of *its low validity* as a prognosis of university success. The first is the possibility that the examinations as conducted at the universities have no more reliability than that of matriculation itself, and I have reason to believe that this is so. You have less chance to hit a target if it is also moving. The second is the fact that a pass in matriculation depends not only on the attainment of 40 per cent. of the possible aggregate but also on obtaining 33⅓ per cent. marks in each individual subject. This system leads to mediocre students who are strong in nothing and equally weak in all subjects arriving at university. In order to avoid the risk of probably failing in his weak subjects a pupil neglects his " safe " subject and devotes

most of his attention to the weak ones. To start with, they have difficulty in planning their courses because they do not know what they are really good at. They lack guidance. What is worse is that the inevitable nemesis of failure overtakes many of them at the end of the year; and failing a subject is not conducive to love of learning for its own sake. These considerations make university success a precarious and uncertain entity, and very difficult to select for with any reasonable amount of accuracy.

I have found that the aggregate when taken by itself irrespective of pass or failure in individual subjects at matriculation correlates better with the student's achievement at university than the matriculation result which involves the passing in all the different subjects as well. (It should be mentioned in passing that if a student obtains a first class aggregate under the existing system but fails in *one* subject, he is given a mere pass in the whole examination.) Whatever other uses the matriculation examination may have, I feel that when it comes to selecting students for university study a better way might be to insist on a higher aggregate, say 50 per cent. or 55 per cent., and not to pay any attention to whether a student has or has not failed in any individual subject or subjects. Supposing even that he has failed in one or more subjects he must have been pretty strong in the other subjects to reach 55 per cent. in the aggregate. Merely to have scraped through his weak subjects would not make him a better student. In any case, he is not likely to take those subjects at university, but will concentrate on his good ones. Any university instructor will tell you that it is much more satisfactory to teach students who have a high level of ability and are keen on their subjects than those mediocre ones who have just obtained a third class pass in all subjects.

This is a matter of opinion and might be argued. The fact is, however, that the matriculation examination, which is an elaborate business costing thousands of pounds every year, is an ineffective instrument of selection. It also has a cramping effect on the schools. And one wonders whether the game is worth the candle.

What is the Alternative?

The question now remains, what alternative method is there?

It has been proposed that post-matriculation classes be introduced in the high schools for those who wish to go to university. This, I am afraid, is impracticable under South African conditions. *In most cases* it will mean sending children away from home *in any case* to the post-matriculation centres. They might as well then go to university where it will be possible to concentrate more effective instructors during the extra year than at high schools scattered all over the country. As it is, we have already more than enough institutions for higher education.

While South African students do not enter university younger than in most other countries, they do have one year less schooling

before they enter than in most countries, because here our children start school at least a year later than in England and Europe, for example. What will be more feasible, therefore, is rather to *add a year at the beginning of the 3 year degree course at the university*. This is to be a probation and orientation year for the student at the end of which he has to submit to a "comprehensive examination."*

Only those who pass that examination will be allowed to enter for the degree courses. Those who fail can stay on "for their health," if they like, provided they pay a higher tuition fee, but they will not be allowed to clutter up the degree courses.

This arrangement throws the onus of selecting students for university study on the university itself, where I think it belongs. The schools, which will then no more have the excuse of the university dominance, could then issue their own high school leaving certificates to those who have successfully completed their high school studies with or without an external departmental examination.

What would be required by the university at entrance will be a cumulative record of a student's school career giving a picture of his scholastic attainments, his social and economic background and his character, together with other facts which may throw light on his possibilities of success as a student at the university.

Where possible, this should be supplemented by an intelligence test given to all students on entering. Such a test, though not infallible, gives at any rate a much higher correlation with university success than do the traditional examinations.

Melbourne University has been admitting students on the headmaster's certificate as well as per examination. About half enter this way. It has been found that this step has in no way lowered the standard of work at the university. On the contrary.

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* By a *comprehensive examination* I mean an examination which measures (a) not only retention of factual materials and applications taught in class or discovered in reading, but also ability to make practical applications of principles to new situations and attitudes toward controversial subjects. (b) The comprehensive examination in a given field should extend to materials covering the student's own reading as well as the class instruction. (c) Lastly, it should demand integration. Test situations should be devised which will demand the drawing together of information and principles from different phases or divisions of a subject. The types of tests usually used include the essay, true-false, modified true-false, multiple choice, reverse multiple choice, multiple response, matching, master-list, classification, completion, controlled completion, and arranging items. (For those who are interested in this type of examination I wish to refer to the *Manual of Examination Methods*, issued by the University of Chicago Board of Examinations, 1933; *Studies in College Examinations*, (Minneapolis, 1934), and Ben D. Wood, *Measurement in Higher Education*, N.Y., 1923.).

While this type of examination is much more difficult to set, it is much more reliable than the traditional examination and takes about one-tenth of the time to score.

I found on checking up the careers of the students for the last 7 years at that university, that those who were admitted on the headmaster's certificate showed better records than those who came in via the examination. Especially in the honours work did the former shine. Let it be noted that the schools which availed themselves of this option were no better schools on the whole than those who took the examinations.

The Need for Guidance.

I mention this example to show that if we trust our teachers more and obtain more detailed information about our students at the university, we shall not thereby lower the standard of our university work. I believe that the opposite will result. And what is of greater significance is that we shall come to realise that, if the function of education is to discover the abilities and aptitudes of pupils and to arrange for them those courses from which they are most capable of profiting, *the central problem accordingly comes to be that of guidance and the development of methods, records and tests which will make such guidance valuable.*

This guidance is essential in the secondary school. Educators must realise that if secondary education is to be provided for all *then it cannot be the same for all.* And with the ever increasing numbers of students coming annually to our universities, guidance is equally essential there. There are too many misfits and failures in the courses students choose. They do not know themselves nor do they know the courses they enter for.

As an illustration of the way in which some students plan their courses let me tell the following experience I had years ago while teaching at the University of Capetown. Together with a number of my colleagues I was sitting in the big hall signing the registration cards for students on registration day. Two attractive girls presented their cards. "What on earth made you choose this curious selection of subjects?" I asked, amazed, for the list was about the most fantastic combination of courses possible. They giggled shyly and said they could not say. Goodnaturedly I insisted, however. At last one of them, whom I happened to know fairly well, came up in a confiding way to me and said: "I'll tell you, sir, if you do not go and split on us." "Very well," I said, "go ahead." "Well, sir, you see, it's like this. Sheila and I here spent a dickens of a time planning our course, because we went carefully through the time table and selected those subjects which would leave us free to go down town to Fletcher and Cartwrights for 11 o'clock tea every day!"

They still had a principle on which to base their choice! Students sometimes base their selection on only slightly less flimsy grounds; such as the looks or manner of the lecturer or professor, his reputation for lenience, etc., etc., or on no ground at all.

These problems are the same the world over.

The rapid changes which society has undergone in modern times, particularly the marked increase in the enrolment of high schools and universities, demand a new orientation in the education of youth. Quite clearly a new era is beginning in which society will *prolong its educational tutelage of youth.* Just as the establishment of universal elementary education was the central problem in the 19th, so in the 20th century there is scarcely a country in the world which is not concerned with the problems both of the education of the adolescent and of higher and professional education.

"The rigid adherence to the tradition of culture, which is characteristic of European education and which is perpetuated by strong social approval on the one hand and official sanctions or privileges on the other, has as its counterpart the protection of a body of highly specialised teachers. The result of this specialisation is that on the whole teachers are more interested in their own subjects than in their pupils as individuals, with two further consequences, that they tend to be exacting in the maintenance of standards of achievement in the subjects which they teach, and that they fail too often to see the bearing of these subjects on the general all-round education of the pupils under their charge. To some extent these consequences also flow from the ever-present pressure of external examinations and of requirements which open the way for the pupils to advancement beyond the secondary school, whether to the universities or to selected occupations."—(Kandel: *Examinations and their substitutes in the United States*, p. 11.)

A Common Foundation of General Education for all University Students.

Let me say a few words about the nature and objectives of this additional year at the beginning of the degree course mentioned above.

(a) Its object, in the first place, is to add one year to the student's general education before he begins to specialise. I would make it compulsory for every student during that first year to study *four major fields of knowledge*:

1. *The Humanities.*—Above all, the student must learn to write his own language with facilty and precision.

2. *The Social Science*, i.e., an interpretation of contemporary civilisation and the conflicting ideologies of to-day in the light of history and philosophy. Incidently, I would prescribe works like the following: Plato's *Republic*, Walter Lippmann's *Enquiry into the principles of the Good Society*, and Professor Bury's *The History of the Freedom of Thought*.

3. *Physical Sciences.*—Chiefly the history of man's efforts to control the forces of nature.

4. *Biological Sciences.*—Chiefly with regard to their application to human life. Paul de Kruif's works. Alexis

Carrel's *Man the Unknown*, Bews' *Human Ecology*, and Hogben's *Science for the Citizen*, indicate the kind of reading they would have to do.

(b) Such a year's work should, in the second place, be designed so as to give the student an acquaintance with the various fields of human thought. That is, it must aim at giving him at least some knowledge on which he can base his choice of subjects for his degree courses. Many a student to-day embarks on Geology or Zoology for example, simply because he has to take one science, without having the faintest idea what he is letting himself in for Usually in such a first course in science he devotes most of his time to acquiring terminology as a foundation for the second and third courses which he never reaches. In fact, many drop these interesting sciences after this first year stage with as little appreciation of the scientific spirit which actuated the great workers of science in those fields as would have been the case had they studied Latin grammar, which is also a triumph in logical classification.

(c) As I said above, I would make these four courses compulsory for every student during his first year at the university, whether he is going to be a doctor, engineer, lawyer, teacher, theologian or a research worker. The reason for this is that we are suffering from over specialisation in higher education. It is even present in the high schools where *subjects* are regarded as separate entities, and pupils are bent on merely acquiring a disconnected and disjointed mass of information dished out to them by specialist teachers who usually see only their own subject during the period allotted to them on the time-table. This brings me to the third objective of the first year (an objective which, by the way, should not be confined to the first year only), viz., that of *integration*.

Consider this situation from the point of view of the citizens whom we are supposed to be educating. They are faced with an increasing complexity of facts when they go out to encounter life, and they are forced to make some kind of synthesis of these facts. Have we helped them to do this? Our undergraduates find the university departmentalised. No one tries to show them the relation between subjects taught in different departments. Hence they become professionalised rather than educated. Doctors go out who are merely technical healers, with little interest in public hygiene and eugenics, let alone the social services and the economic structure of society. Lawyers go out, for the most part, with little interest in the philosophy of law or the functions of legislation, let alone the idea of an international rule of law. Engineers run the increasingly elaborate plan of modern society with no thought of the social effects of the mechanism they serve rather than control.

It may not be possible for us to integrate all knowledge at universities, but I feel sure we could do a great deal more than

is done at present. But if one makes this suggestion one comes up against the specialists straightaway. "Let the cobbler stick to his last," they say, forgetting that the last itself tends to grow smaller and smaller, and that man does not live in shoes alone. "We don't want the all-rounder," they say. "We don't want the man who knows a little about a lot of things, because he knows little about anything at all." The obvious retort is "Do we want only the man who knows more and more about less and less?"

When European education was controlled by the Church in the Middle Ages, the Church did make some attempt to integrate the knowledge she taught. We may not be able to accept the principles of her synthesis, but need we give up the ideal of integration as completely as we have done? Universities are places where knowledge is increased as well as imparted, and research is necessary. But must all research be along narrow specialist lines? Cannot some of us, at least, research into the problem of tying up, of integrating, of putting things together instead of pulling them apart? What is new knowledge? Must it always be new concrete facts. Can it not also be the perception of a new relationship between already known facts in different spheres?

"In every sphere of university teaching," says Professor G. V. Portus of Adelaide University, in a recent lecture given in London, "*integration seems to me to be the crying need.* Professional students need a composite course in the history of science, in logic, in the records of religious persecution, in the history of sanitation, in short, in the difficulty of securing human co-operation. It could be sketchy and done on broad lines, but let it be a tie-up, relating their specialised knowledge to the problems of social life. It could be as disorderly as a beer-garden, as inconclusive as a merry-go-round, so long as these young doctors and engineers and lawyers and dentists were led to an intelligent interest in the wider world they are going to encounter, and for the greater part of which their specialist studies offer no sort of initiation. Even inside separate faculties we are neglecting this unifying function. Literature, history, political science, economics, psychology, and anthropology are all vitally interdependent, yet we leave it almost entirely to the students to draw these subjects together." I find myself in absolute agreement with Professor Portus.

The kind of thing I have in mind is the exposition which Professor Bews gave in his two works, *Human Ecology* and *Life as a whole*.

The most essential thing, however, about this first year of orientation is that only the best *teachers* should be entrusted with this task. They must be men who not only stand high in their respective fields and have that synthetic point of view, but they must also be inspiring teachers—sufficiently close to the life and

interests of the first year student to rouse enthusiasm rather than distaste for a subject. I have in mind the kind of course in science that a D'Arcy Thompson or a Julian Huxley would give to a group of young people from 18 to 19 years old. There should not be more than three lectures per week in each of the four fields, i.e. twelve in all. These lectures might be made optional. The lecturer will therefore have to survive on merit. Even though every lecture is attended it will leave at least a whole morning or whole afternoon free each day in which a student can have time to read. This should be done under the guidance of a tutor. Only too often does one find that the greater part of the first year at the university is wasted by students owing to the fact that they are not used to the new freedom. As this is the transition year between school and university work the chief function of the tutors during this year will be guidance and finding out in which directions the student's aptitudes lie.

This will mean additional staff at the universities and additional cost, but it seems to be the only way in which to alleviate the deplorable waste going on in our institutions to-day. After all, the thing that matters in education is the interplay of personality between teacher and student. This is much more important than examinations.

I have dozens of graduate research students from different universities working with me on various problems from time to time. I am sometimes amazed at their almost pathetic ignorance of the world's great ideas and of the men who laid the foundations of modern thought. Recently, I found some of them, who even boasted of M.A. degrees, who could not tell me who Darwin was, when he lived and what his contribution to modern thought was. The nearest they got was that " Darwin said men were descended from monkeys " or " Darwin's teachings were against the Bible." I mention this here because I am convinced that we shall never get as far in the advancement of science and research in this country as we would like, until we can guarantee a better all-round development for our young specialists. Then and then only will the university, as Whitehead so beautifully expresses it, lead our young men to " the imaginative consideration of learning."

Though it might seem that I have strayed pretty far away from my main topic, the validity of the matriculation examination, it will serve to bring home to you how far-reaching this problem of validity is, because it involves not only the relationship between secondary and tertiary education, but also a consideration of the ultimate aim of education in relation to society. The task which confronts educators to-day is not one of separating the sheep from the goats, of dividing the population into those who have passed and those who have failed, or of setting up the curriculum as a hurdle to be overcome. With the inevitable prolongation of " infancy," in the sense used by John Fiske, due in part to economic reasons and in part to the extension of the

compulsory age for school attendance, *the problem has ceased to be one of selection and has become one of the distribution of education*, or the discovery of "the right education for the right pupil under the right teacher." The success of an educational system can or should no longer be measured in terms of the numbers who pass or fail in examinations but by the degree to which it has been able to discover the abilities and needs of pupils and students and has provided for them the type of education from which they are capable of profiting. And for this purpose the traditional type of examination cannot be used, for the problem is not merely one of selecting an élite or élites, since the types of leaders required by modern societies have increased in numbers, but of giving to all the type of education and instruction that will equip them, in accordance with their abilities, to be useful members of society.

(b) Reliability.

Now let us turn to the second criterion of examinations, viz.. reliability. Above we saw that validity was the degree to which an examination measures what it is intended to measure, and this opened up an enormous vista of problems which we tried briefly to look at. *Reliability*, however, is the degree to which the scores or marks obtained in an examination at one time agree with scores or marks made by the same pupils in a similar or equivalent examination at another time. The matriculation examinations do not measure the same pupils year after year but, as we shall try to show later, they measure large groups of children of practically equal ability and preparation with what is supposed to be a test of the same standard.

The consideration of reliability is crucial because *without reliability there cannot be validity*. The relationship between reliability and validity is, however, one-sided. As Professor Spearman puts it: "Low reliability involves low validity but the converse is not true. Wherever we find bad agreement between the different measurements we can safely say the examination is bad. But when the measurements agree, we cannot forthwith say that the examination is good."

Reliability though subordinate to validity, is nevertheless a *sine qua non* for the validity of an examination.

Variation of Standard from Year to Year.

This aspect of our examinations, therefore, deserves serious study in South Africa. Let us look at the matriculation examination from this aspect of reliability. The accompanying table shows the great variation from year to year in the percentage of candidates failing the three possible kinds of matriculation in South Africa. First there is the Joint Matriculation Board examination which before 1918 was conducted by the University of the Cape of Good Hope. The Cape and Transvaal Education Departments introduced their own departmental examinations in 1924 and 1922

respectively. Next year the O.F.S. Education Department will conduct its own examination.

Percentage of Failures in

Year.	J.M.B. Matriculation.	Cape. Senior Certificate.	Transvaal. School Leaving Certicate.
1910	60	—	—
1911	40	—	—
1912	44	—	—
1913	56	—	—
1914	46	—	—
1915	41	—	—
1916	28	—	—
1917	37	—	—
1918	36	—	—
1919	51	—	—
1920	46	—	—
1921	46	—	—
1922	46	—	31
1923	57	—	47
1924	44	30	45
1925	49	30	36
1926	42	37	37
1927	42	32	34
1928	13	26	32
1929	42	24	28
1930	40	20	32
1931	43	24	38
1932	38	22	29
1933	33	23	35
1934	42	19	29
1935	37	22	29

By way of illustration let me quote a few of the extreme variations. Taking the Joint Matriculation Board column first. In 1910 60 per cent. failed. During the next two years the percentage of failures dropped to 40 and 44 per cent. respectively. In 1913 it stood up at 56 per cent. again and in 1916 dropped to 28 per cent. In 1919 it was up at 51 per cent. In latter years the variation has decreased somewhat. For example in 1931 it was 43 per cent. and in 1933 33 per cent. Yet in 1934 it was up at 42 per cent. again. The range of variation for the Cape Senior Certificate can be indicated by the following extreme cases. In 1926 37 per cent. failed; in 1930 20 per cent., in 1934 19 per cent., and in 1935 22 per cent. The variation in the Transvaal High School Leaving Certificate has about the same range as the Cape. For example, the Transvaal had 47 per cent. failures in 1923 and only 28 per cent. in 1929. We have here to do with large numbers of candidates—e.g., in 1935 the Joint Matriculation Board had 2,384, Cape 3,165 and the Transvaal 1,823 candidates sitting for the examination.

While one often finds in one school that a particular class in one year differs in ability from the class of the next year, it is very unlikely that the thousands of children in all the schools of a province or of a number of provinces will differ to any appreciable extent from those of the next year. In fact, where standardised intelligence tests (which have a high reliability as measures) have been applied on a large scale it has been demonstrated that there is nothing more constant than the average ability of such large groups of pupils from one year to another.

Nor is it likely that the preparation of these candidates in the country as a whole will all of a sudden be so bad one year as to warrant nearly twice as many failures as in the previous year, or that in the next year they become all of a sudden twice as good. The teachers are the same and the pupils are the same. The pupils of the country as a whole are not like crops which are subject to blight and yield a poor harvest one year and a good one the next. The only conclusion one can come to, is that *the variation must be in the standard of the examination set.* If there had been a steady trend in one direction in these results, one might still allow that there might be some other factors at work, e.g., the better or worse preparation of students. But these percentages jump about so haphazardly that it is hard to believe that the standard of these examinations has been the same from one year to the next. and that it was the education of the pupils which fluctuated in that way.

There are at present four examining bodies in South Africa for matriculation: The Cape Education Department, the Transvaal Education Department, the Union Education Department and the Joint Matriculation Board. With the O.F.S. coming in next year there will be five. The Joint Matriculation Board is the co-ordinating or moderating body which, *inter alia*, is supposed to ensure that a more or less equal standard is maintained by these bodies. At any rate, the various matriculation certificates are assumed to be equivalent by the universities, the public service and other employers who require matriculation as an educational qualification. The Board deals with reciprocity of recognition of similar certificates in other countries.

Variation in Standard amongst Examining Bodies.

From the above figures it will be evident that these examinations differ greatly in their eliminative power, not only from year to year, but also from one examining body to the other. For example, the average percentage of failures varies: the figure for the Joint Matriculation Board during the six years (1930-35) was 39 per cent., in the Cape Senior Certificate 22 per cent. and Transvaal 32 per cent.

Also the chances of obtaining a first class pass from these various examining bodies differ greatly. Over a period of six years (1930-35) the Joint Matriculation Board showed an average of

17·1 per cent. first class passes. The Cape had 13·5 per cent, while the Transvaal had only 8·5 per cent. (1932-35) first classes.

In a recent study I made of failures in all high schools during 1935 I found that the chances of a school getting from 90 per cent. to 100 per cent. of its candidates through the matriculation examination are about 4 times as big in the Cape as in the Transvaal and Natal. I could not obtain data for the O.F.S.

Of course, there is always the possibility that the Cape schools may be better, but I would be the last person to draw such a conclusion from this evidence. The chances are, however, very strong that the standards of these different examinations are (contrary to popular belief) by no means the same.

Unfortunately schools compete with each other for results and advertise percentages of passes. The public* attaches a great deal of importance to them; *rightly*, because it is a question of vital importance to a parent whether his child passes or fails, obtains a bursary or not a bursary (a boy's whole future career is often determined by such a result), and *wrongly*, I think, if they take such results as an index of the real education a boy has received or of the efficacy of the school he has attended or of the Education Department under which such a school falls.

So much for the variation of the results of the *examination as a whole*. The variation in the percentage of failure in individual subjects is even greater, as may be expected. These variations are in the failures in one subject from one year to another and in different subjects in the same year.

I am not in a position now to give you details with regard to individual subjects. I can, however, state the general fact that it frequently happens in the case of subjects taken by hundreds or even thousands of candidates, that twice and even three times as many candidates fail in the same subject from one year to the next. How can this be possible when the syllabus and the requirements for that subject are exactly the same? Is it possible, for example, that the science teachers in one year all of a sudden have gone stale, while in the same year language teachers do twice as brilliant work as in the previous year? Can it be that the pupils of a whole province (who by the time they arrive in the last year of their high school are after all the product of influences which must be very constant on an average throughout the country) have suddenly in one year become bereft of learning capacity in a particular subject while they shine in another subject in the same year or in the same subject in another year? It will be a bold person to answer these questions in the affirmative.

*Perhaps the layman's point of view with regard to this question is best summed up by the remark once made by the Marquess of Linlithgow: "I detest examinations as much as anybody; but I distrust profoundly the man who cannot pass them."—Quoted by Sir Percy Nunn at the Carnegie Conference on Examinations at Folkstone, 1936.

Without proof I could not. Will it not be more reasonable to assume that the variability lies with the standard of these examination papers and their marking? I have in mind here particularly those examinations taken by large numbers of candidates, say over 450.

To be sure, the examination authorities in South Africa are not oblivious to these fluctuations. They have in recent years appointed special statistical committees to try and remedy the situation. The matter is, therefore, receiving attention. Unfortunately all such reforms come very gradually as the whole matter is beset with difficulties and sudden changes from the traditional system are not always possible even if desirable.

The Cape Education Department was the first examining body which, as a result of representations made by the S.A. Teachers' Association, made a deliberate attempt to stabilise the percentage of failures from year to year. It will be noticed in the table above that the Cape's figures fluctuate less than those of the other two examining bodies. The Cape also uses a scaled addition or deduction in adjusting marks, which is more scientific than merely adding or deducting a fixed number of marks in making adjustments as, for example, the Transvaal does.

The underlying principle is as formulated by the American College Entrance Board—probably the most conservative examining body in the U.S.A.—viz., "*It is more conservative to assume that the populations taking the examinations are comparatively stable, while the examinations vary in difficulty, than to assume that the difficulty of the examination is constant and that the quality of the preparation varies.*"

In other words, the constancy of the examination population should be assumed unless there is definite evidence to the contrary. For example, there are good reasons to believe that the constitution of the matriculants sitting for the Joint Matriculation Board examinations is not exactly the same as that of those sitting for the Cape and Transvaal examinations, because the former has a considerable proportion of private entries and natives. This proportion will be even greater when the O.F.S. withdraws all its candidates and sets up its own examination next year. The Joint Matriculation Board will then be left only with the candidates from Natal, from private schools and with private entries.

Space does not permit me to discuss the various methods of statistical control in detail.

The fundamental principle which underlies such methods in the normal examination is that *the achievement of the group* as a whole in a particular subject is to set the standard in that subject and not the examiner. This is the principle underlying all the examination reforms in England, e.g., the Joint Matriculation Board in Great Britain, and also in the college entrance board examinations in the U.S.A.

Rather than saying that a candidate has reached such and such a *percentage of marks* it is better to report that his position

in the group examined is such and such a *percentile*. After all, percentages mean nothing objective. When I was examiner in the United States I found that 60 per cent. was failing mark and 90 per cent. not uncommon in school as well as university examinations. And with that they fail even less candidates than we do with a 40 per cent. minimum.

Examiners' marks should, therefore, in all subjects, where there are say at least 400 or 500 candidates, be rescaled by means of a normative percentile curve or converted into "standard" scores.

For reasons which I shall presently mention, this should be obligatory and not permissive as is at present the case. The normal probability curve will be found more practically useful than any other kind of ogive curve, because so many values have been worked out for it and statistical adjustment is essential with it.

At any rate this will prove a more scientific procedure in the long run than the present one where the previous year's ogive curve combining the marks of a number of previous years is used, thus capitalising all the faults of the methods of previous years

In subjects where the numbers of candidates are less than 400 there is a fairly simple statistical device by which those marks also can be adjusted in an equitable way.

The Inequality of Units of Measurement.

Only by equating marks in terms of percentile rank or better still by means of "standard scores" for all subjects can one be sure that when one is combining the marks into an aggregate, one is adding together units of the same magnitude. This is unfortunately not done to-day by any of the examining bodies in South Africa and is one of the reasons probably why the marks still fluctuate in such an arbitrary way.

It is an actual fact that 10 marks e.g., in history, do not mean the same as 10 marks in mathematics or in chemistry. And to add them together as if they were equal units into one aggregate is like adding sheep and cows. 5 sheep plus 10 cows is not the same as 10 sheep plus 5 cows, even though the result is 15 in each case.

Yet in the arithmetic of examination marks these two aggregates are regarded as equal, for the purpose of classifying candidates into fail, pass or first class.

On account of their different standard deviations, different subjects have a different pulling power on the aggregate, even though their maxima might be the same. This elementary fact is disregarded by practically all people having to do with examinations in primary and secondary schools and at universities in South Africa.

When I was working on the Poor White survey about 10 years ago I was faced with a problem which illustrates this statistical point rather better than to talk about cows and sheep. We wanted to obtain some indication of the physical condition of children, and the medical officer took three measures: (a) their weight in lbs.; (b) their sitting heights in inches; and (c) their chest measurements in inches. It was obvious that we could not just add these three measures together to give us what we were after, viz., a nutritional index. The reason why we could not do that was because a difference of two inches in the chest measurements of two children was a much more significant difference than a difference of two lbs. in their weights. If we added the units together merely as they were, the differences in weight would have wiped out the differences in chest measurement and in sitting height. The only method of combining them was first to reduce these three measures to standard scores, i.e., in terms of the variability of the group and then to add these. This was the only way in which we could get an index which reflected in some real way the physical condition of our children.

It is easy to prove statistically that to add e.g., raw history marks to maths. marks is just as unscientific as to add inches to pounds, because they are quite as different units as what inches and pounds are.

The reason I stress this particular point is because in South Africa we use the *aggregate* to place pupils in different classes and also to award them scholarships. Whenever, therefore, we have to do with examining of any kind, it ought to be a matter of conscience with us who use scientifically defensible procedures in our respective scientific fields, to demand the same in measurements which affect profoundly the educational careers of our young people.

The chief reason for delay in reform in this country as in other countries is sheer traditionalism.

South Africa is, however, not the only country which is struggling with this problem of examinations—nor are our examinations as conducted here any worse than the traditional examinations conducted overseas. The problem and the dissatisfaction are world-wide.

Statistical Control Alone not Justified.

I may have given you the impression from my discussion of reliability that the trouble was merely a matter of statistical control and that once we have stabilised our percentages of failures or equalised the units we use to measure with we shall have reliable examinations. No, the trouble is much more deep-seated and serious. It lies in the irregularity of the judgment of individual examiners when using the traditional kind of examination paper which we have, for example, in the matric. Such irregularity is not only formidable but is one which no

ordinary statistical analysis would detect at all. To use the words of Sir Philip Hartog who was chairman of the English Committee investigating the reliability of examinations in England under the International Examinations Enquiry: "If you have two assistant examiners with the same statistics, with the same average and the same distribution, an examining authority naturally thinks that everything is all right. Everything is not all right."

Why is everything not all right? This was one of the questions which the *International Examinations Enquiry* decided to tackle. This enquiry was made possible by the generosity and interest of the Carnegie Corporation and the Carnegie Foundation, who called together in 1931 to a conference at Eastbourne under the chairmanship of Professor Paul Monroe all the best brains in the educational world from Great Britain, America, Germany, France and Switzerland. This conference outlined the main problems which were, of course, different in the respective countries because of differences in the national systems of education and culture. National committees were accordingly appointed in each of the countries represented to study the problem in ways most appropriate to their own situation. They were to report again in five years' time. The United States was almost a generation ahead of the other countries in experiments involving the reliability of examinations, so it did not need convincing on that particular point. Germany was confronted with a very practical and urgent situation; secondary schools and universities were overcrowded; professions were overcrowded. Selection was a real issue. The German Republic was therefore in any case more ready for experimentation than either France or England. In the latter country Sir Philip Hartog, the Director of the Inquiry, in seeking the co-operation of one of the universities in the investigation was met by the statement, "We think that here we know everything there is to be known about examinations;" in the former M. Desclos, the Director of the French Inquiry, attributed the failure of more than 2,800 out of 3,000 teachers and administrators to reply to a questionnaire on examinations to the fact that they had no doubt as to the impeccability of the findings of the examiners, who could be trusted to continue their work to the satisfaction of all concerned.

This atmosphere of complacency in these two countries determined the nature of the task of the English and French Committees; they had to prove in the most accurate and convincing manner possible the unreliability of marking in the existing practice of examinations in order to shake the prevailing complacency and before further investigations looking to reform could be undertaken.

The results of these investigations proved rather a shock to those who were so complacent about their own reliability of marking.

Variability in Judgment of Examiners.

Let me outline the method and work of the *English Committee* by way of example. This committee devoted its investigations to testing concurrences of a number of independent examiners and of independent boards of examiners in marking the same set of papers; the purpose of the second study was to test the claim that individual idiosyncrasies of examiners were ironed out when marking was done by a board. As compared with earlier experiments conducted in the U.S.A., the papers used in the investigations were actual papers written in actual examinations. These papers covered a wide range of examinations, both qualifying and selective, and included papers written in the eleven plus or special place examination, a college scholarship examinaiton, university honours examinations in history and mathematics, and secondary school certificate examinations in Latin, French, chemistry and history. An investigation was also conducted on the method of interview on the model of the Civil Service Examination. Examiners were selected from actual examining panels. were paid, and were given all the time they needed. Every known variation of the examining technique was used in order to ensure accuracy—the same system of marking was employed as in the original examination; the same examiners marked the same papers twice at an interval of a year; two groups of examiners were employed on the same papers; general standards and details of marking were discussed in two groups of examiners under the direction of chief examiners; trial markings were submitted to criticism; an English essay was marked once by general impression and then by details; and numerical and literal marks were given.

The French Committee proceeded on its investigations along much the same lines, but concentrated more specifically upon the most crucial of French examinations—the baccalauréat, which comes at the close of secondary education.

The main results of the English Committee's work were published in *The Marks of Examiners*, 1936, of which *An Examination of Examinations* was a summary, and in the *Conference on Examinations*, Folkstone, 1936 (published by the Bureau of Publications, Teachers College, Columbia University, N.Y.)

By way of illustration let me give you a few examples of the findings of the English Committee. I shall use as nearly as possible the words of Sir Philip Hartog, the Chairman of that Committee. The first was that of the School Certificate History examination, which corresponds to our Matriculation, more or less. They took 15 actual scripts that had received exactly the same mark by the original examining body. These scripts were sent in turn to 15 examiners, all of whom belonged to the same panel of another examination authority, and were used to team work. These scripts received forty-two different marks varying

from 21 to 70. A year later these scripts were sent to the same examiners in turn (of course, no marks were put on the scripts themselves, nor did the examiners keep any records of their previous work). One man could not act the second time, so there were 14. This time the range was from 16 to 71 marks. But perhaps the most striking feature in the investigation was this. The examiners were asked to award, not only numerical marks, but to classify the papers into three groups (1) Failure (2) Pass (3) Honours. These verdicts are of the utmost importance to the candidate for the School Certificate Examination. Not only has the candidate to pass the examination, but he has to have a certain number of honours passes or credits, as they call it, to be admitted to a university. Now, if you reckon out the figures, you find that when 14 examiners mark 15 candidates they have to give 210 verdicts on each occasion. In 92 out of 210 the verdict of the examiners on the second occasion, was different from that on the first, i.e., candidates would fail who had previously passed or vice versa; or candidates would get honours who had previously merely passed. In nine cases candidates were moved two classes up or down. One examiner changed his verdict in regard to eight out of the 15 candidates, yet he only varied his average by a unit. He awarded the same number of Failure marks, one less Pass and one more Honours; but (and here's the snag) *the same verdicts were given to different candidates*!

These distributions of the marks of candidates as a group would have satisfied the statistical requirements of any board, because the average marks were the same and the spread the same. But heaven only would know what happened to the individual candidate.

Similar experiments were made in other subjects—as indicated above. In Latin and French and Mathematics, the variations were less wild than in the History examination quoted above because they used a more detailed marking scheme. In Latin they used two groups of examiners. In one case the six examiners awarded to the 15 scripts 24 different marks ranging from 28 to 55, and in the other case the seven examiners awarded twenty-eight different marks ranging from 33 to 61. Mind you, these scripts had been given the same mark in the actual examination.

The Unreliability of Traditional Methods of Examinations.

Let me quote the actual report as made by Sir Philip Hartog regarding the French examination. "With the French scripts, instead of circulating the original scripts, we had them reproduced photographically. We selected fifty, and our two examining boards in French (and also in Chemistry) followed precisely a procedure which is now often regarded as impeccable. First of all the chief examiner drew up a marking scheme, and then he summoned a meeting of his board; the board had a number of

trial-scripts on the table, the details of which all the members discussed; they marked scripts at the meeting to see that they were all agreed, and that the majority, at any rate, of their difficulties had been settled. Then they went home, and they were sent other trial-scripts which they marked and sent back to the chief examiner, so that he might see if there were any further difficulties, and so that he might check the marking and reprove his assistant examiners for any mistakes that they had made; then each examiner received identical photographs of the fifty different scripts. But mark, the rôle of the chief examiner did not end there. He received about a fifth of the scripts (I think about ten scripts marked by each examiner) and he judged the standard of the individual examiners from these ten scripts, and gave directions as to how the total marks were to be altered. They might be raised 5 per cent. or lowered 5 per cent. He gave just exactly the same detailed marking instructions with regard to them that he would have given if it had been an actual examination. We followed in every detail the usual process of such boards of examiners. Now, let us take the verdict of the individual examiners after they had settled the standards for marks for Failure, Passes and Credits, and see what they are. The returns of these individual examiners showed that the number of Failures varied from 6 to 15, the number of Passes from 7 to 16, of Credits from 21 to 30, and of Distinctions from 1 to 9; and this is the kind of method that is regarded as infallible at the present moment in the university town where they know everything about examinations."

The average as well as the extreme ranges of marks differed considerably between the two Boards. You find in the two Boards a difference of principle, viz., in the way they give different marks to different parts of the same paper. It is perfectly obvious that with two such boards, the fate of a candidate may be entirely different. What it means is that when a boy goes in for a French examination under the present system, it may be a matter of chance whether he gets a board like Board I or a board like Board II; it may be a matter of chance whether he passes or fails; and it may be a matter of chance whether he has to wait another year before he goes to a university, or whether he is prevented altogether from going to a university by his failure.

Even in Arithmetic and Mathematics there were disturbing variations between the marks of individual candidates, though the range was smaller as one would naturally expect.

The personal interview and oral examinations were also subjected to this same scrutiny and found wanting in reliability to a most shocking extent. It is impossible for me here to give further details; you will find them in *The Marks of Examiners* by Hartog and Rhodes. Let me quote, however, just one more instance. In one of these experiments it happened that one of the model answer papers written out by one of the examiners

himself for his own guidance, by accident got mixed up with the other papers. The marks awarded to that paper by his own colleagues ranged from 40 to 90 per cent. These are men of high repute in university and educational circles and experienced examiners.

The reason I have quoted these examples at some length is to show that when I plead here for a systematic investigation into our methods of examination in this country, I do not wish it to be construed as indicating that the S.A. Matriculation examinations are worse than the traditional examinations in England, for example.

The traditional examinations are all bad because the system is wrong. They try to do the impossible. As Dr. Crofts, the registrar of the Joint Matriculation Board in Great Britain puts it: "Considerable experience of examiners' meetings does not inspire confidence in their awards, however much faith one puts in each examiner individually, and notwithstanding the seriousness with which examiners invariably approach such matters. The task, in short, is beyond them."

I cannot do better in concluding this account of the International Examinations Enquiry than to quote the remarks made by Professor Thorndike at the 1935 Conference on Examinations when they were discussing the reports of the various national committees: "I have always revered the British examinations. The examinations in the United States have been casual; they have been local. The teacher makes an examination for his own class, and it is often done perfunctorily. We have found them very bad. I felt, however, that the examinations in England were done with much greater care and with much more seriousness. The principle of outside examination has its difficulties, but it has also its merits, notably, great care in preparation and in scoring. I was, however, pretty well converted by Mr. Valentine's book and by other studies to the belief that the best examinations by the old methods are bad too; and, frankly, I am entirely convinced by this Report. Leave out its results on interviews; that is a small experiment in an enormous matter. In the educational examinations for passing, for honours, and for privileges—in all three cases it seems to me that the old type of examination has been found wanting in the sense that the care and outlay of money and time that are given to it do not enable it to produce a good result. That is my judgment. I hope they have better examinations in France and Germany than they have in England, but I have a very strong feeling now that the difficulty lies in the system itself, that a human being inspecting an hour's work of another human being made after the conventional plan, cannot do better than attain a very rough and approximate result, a result which is very variable. It will serve if you have to determine the difference between a man and a dog, or the difference between a genius and an idiot; but when we come to fine distinctions, which in practice we do need to

make in order to avoid individual injustice, and in order to get the best advantage from examinations for the social welfare, it does seem to me that the historical system is not a very strong support; it seems rather a weak reed."

The French who were so very superior and sceptical about this whole investigation came to the conference in a much more modest and chastened mood. As M. Henri Laugier put it: " It will probably be one of the great merits, among others, of the different Carnegie inquiries, to have brought to light the discrepancies between examiners, to have measured them, to have shown that they exceed the worst fears of the most pessimistic, to have convinced the sceptics that one cannot become an examiner without preparation, that such a profession is a subtle one which calls for natural gifts and apprenticeship in a delicate technique."

From what I have stated above, it seems to me absolutely essential that all those who have to do with teaching and examining should face this problem honestly.

The present method is inefficient, and although the impartiality of the examination is undoubted, it is the impartiality of chance, and what you have is the unfairness of chance.

One Way Out of the Difficulty.

I am not one of those who shout " abolish all examinations." As long as we have education we must have examinations. The harmful influence is not due to examinations as such but to *bad* examinations. Nor do I agree that examinations are a necessary evil. If they are evil they should not be necessary. If they are necessary they should not be evil. It is up to us as scientists to devise ways and means by which we can increase their reliability as well as their validity.

One of the ways in which this has been done is by means of the so-called *new type tests*. This new type test or the objective examination is a form of test which seeks to reduce the weaknesses and defects of the essay type and which yields objective results which are valid, reliable, accurate and comparable in similar situations. Its chief characteristics are that it calls for a short answer by one or a few words, by a check mark, or by a number, and can be answered only if the student has the pertinent knowledge readily available.

For example a student is faced with a statement like the following: " The problem of capital vs. labour had no place in the guild system of early modern times." To deal adequately with a hundred such statements which are either true or false requires not only knowledge but also the power to *think* in the field from which the statements are drawn.

The point that must be stressed, however, is that those who have been the leaders in advocating the use of the new type test have not urged that it should displace the essay form, the value

of which they are the first to recognise, but rather that the new type is an added better instrument not only for measuring reasoning and amount of information acquired but also for other purposes which are important educational controls.

The new type test is considered superior to the old for a variety of reasons, among them the following: (1) It meets standards of validity, that is, it measures what it is designed to measure to the exclusion of factors irrelevant to this particular end. (2) It is reliable in the sense that the scores are so accurate and consistent that they would always be the same no matter what the number of examiners might be. (3) It is objective in that subjective factors such as bias, prejudices, personal opinions and temperament, are eliminated in scoring the examinations. (4) It may be made accurate in the sense that the units of measurement may be made equal at all points of the scale. (5) It is more comprehensive because it includes a wider sampling of the subject of the examination and to that extent is also more reliable. (6) It is easily administered and scored with economy of time and effort for both examiners and pupil; but it requires more time to prepare so that the standards of scientific measurement are adequately met. (7) The results can more easily be interpreted and used for specific purposes of improvement of weaknesses or encouragement of ability.

Unreliability in an examination paper may be caused by three types of factors: (1) Factors which affect the person taking the examination, e.g., his physical and emotional condition, etc. (2) Factors inherent in the paper itself, i.e., the way the questions are framed, ambiguities, etc. Sometimes a paper strikes blind spots in the syllabus, etc. (3) Factors connected primarily with the marking of the paper, i.e., who the particular examiner is, his judgment and mental condition, e.g., whether he marks the paper before or after dinner, etc.

It is difficult to control and correct factors of the first type, viz., those affecting the student's condition when taking the examination. These will be present in any kind of test. Factors of the second type are largely minimised by the new type test, because of its greater comprehensiveness. Factors of the third type, viz., the variability in the marking, are almost entirely eliminated by the new type examination, as it does not matter what examiner marks the paper, whether he does it before or after dinner, the score will be the same.

It is, therefore, by eliminating the operation of this last group of factors which are the most serious for the individual candidate, that the new type test is much superior to the traditional examination.

Incidentally, the adoption of new type tests will make it possible to have the results of an examination as extensive as matriculation ready in a week after writing the examination—a consideration which has much to commend it in South Africa.

CONCLUSION.

In conclusion I wish to make two points. The first is to appeal to you that if and when it becomes possible for us in South Africa to carry out experiments with a view to improving our techniques in examinations you will give your co-operation. Remember that all the natural sciences have advanced in proportion as they have evolved accurate methods of measurement, and that if we want to advance the scientific bases of education we must have definite and exact knowledge of what changes we are making and ought to make in human beings.

And lastly, we must try to get both students and teachers away from the idea that examination day is Judgment Day. Rather look upon examinations and tests as means by which to explore the abilities and needs of students in order to give them better guidance.

Examinations are a means to an end and not an end in themselves. At most they can assist us (in the words of Sir Graham Balfour) " to enable the right pupils to receive the right education from the right teachers, at a cost within the means of the State under conditions which will enable the pupils best to profit by their training."

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MORNING AND MIDDAY RELATIVE HUMIDITIES AT PIETERMARITZBURG, SOUTH AFRICA

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Natal University College, Pietermaritzburg.

Read 5 July, 1938.

In Table I a summary is given of the values of morning and midday percentage relative humidities at Pietermaritzburg, for the period 1st June, 1937 to 31st May, 1938. The results were obtained by means of wet and dry bulb thermometers mounted four feet from the ground in a standard Stevenson's screen in the University College grounds. On days when it was, for various reasons, inconvenient to visit the screen, the midday readings were taken by means of an Assmann psychrometer at one or the other of our residences near the College. In our experience, results obtained simultaneously in the screen at the College and with the Assmann psychrometer at either of the alternative sites, were not found to differ by more than 3 per cent. relative humidity.

The morning readings were usually taken at 8.30 a.m., S.A.S.T., but during term it was necessary once a week, owing to other duties, to take the morning readings at 8 a.m. The readings here referred to for brevity as midday readings were normally taken between 12.30 and 1 p.m.

Attention is drawn to the following interesting features of the readings (see Table I).

1. The comparatively low mean midday relative humidity of 50 per cent., which is 24 per cent. less than the mean morning humidity.

2. The record of a relative humidity as low as 5 per cent. in September.

3. The occurrence in every month of the year, with the exceptions of January and February, of midday relative humidities less than 20 per cent.

4. That midday relative humidity was as much as 69 per cent. below the morning humidity of the same day.

5. The total of 174 days in the year on which midday relative humidity was less than 50 per cent.

The very low midday humidities in September, October and November occurred on days on which the hot north or "Berg" winds were blowing.

TABLE I—Morning and Midday Percentage Relative Humidities at Pietermaritzburg.

Month.	Mean Relative Humidity. %		Absolute Minimum Relative Humidity. %		Number of Days <50% Relative Humidity.		Difference Between Morning and Midday Relative Humidity. %		Rainfall. mm.
	Morn.	Midday.	Morn.	Midday.	Morn.	Midday.	Mean.	Maximum.	
January	76	59	47	21	3	8	17	39	95·3
February	80	59	56	33	0	8	21	53	154·8
March	77	53	40	14	1	10	24	66	38·9
April	87	57	70	16	0	12	30	69	151·2
May	79	48	50	17	0	17	31	54	2·4
June	64	32	33	12	8	24	32	62	18·4
July	61	36	35	15	8	24	25	67	11·1
August	75	38	25	12	2	22	37	68	5·8
September	65	40	23	5	6	19	25	56	17·1
October	72	60	18	9	6	8	12	48	52·5
November	70	51	31	9	3	14	19	44	100·8
December	78	62	40	15	2	8	17	45	160·3
Year	74	50	18	5	39	174	24	69	808·9

During a portion of December, 1937 and January, 1938, which one of us spent on the Natal north coast, twenty-eight results for morning and midday humidities were obtained at Umhlali Beach by means of a whirling hygrometer. The mean morning relative humidity was 81 per cent., and the mean midday relative humidity also 81 per cent. The means of the Pietermaritzburg values for the same period were 78 per cent. and 61 per cent. respectively. During this period, therefore, the mean morning relative humidity at Pietermaritzburg was 3 per cent. less than that at Umhlali, and the mean midday relative humidity at Pietermaritzburg 20 per cent. less than that at the coast. It is clear, therefore, that comparison of morning humidities gives a poor idea of the actual differences in atmospheric humidity between the coast belt and midlands of Natal.

While from the ecological standpoint, the reduction in relative humidity at midday is the factor of chief importance, it is of interest from the physical point of view to examine the extent to which changes in relative humidity are accompanied by changes in the absolute amount of water vapour present in the atmosphere. On days of extreme desiccation there are large variations in water vapour content, as is shown by the data in Table II for the 26th September, 1937, but on more moderate days these variations are less, and in some cases the actual mass of water vapour may show considerable increase even though there is a large drop in the relative humidity.

TABLE II—Mass of Water Vapour in the Atmosphere in grains per cubic foot (1) at Pietermaritzburg on Certain Selected Days.

Date.	Time.	Air Temperature. °F.	Relative Humidity. %	Mass of Water Vapour Grains per Cub. Ft.
26- 9-37	9·00	83	14	1·68
,,	11·00	93	7	1·13
,,	13·00	97	5	0·91
,,	15·00	96·5	5	0·89
,,	17·00	94	9	1·66
,,	18·10	84	15	1·86
,,	19·30	77	24	2·39
,,	22·00	69	47	3·63
1- 7-37	8·30	53·6	61	3·23
,,	12·30	75·5	15	1·42
10- 7-37	8·30	60·0	65	3·74
,,	12·30	75·0	39	3·75
18- 7-37	8·30	45·7	66	2·31
,,	12·30	72·6	37	3·20
18-10-37	8·30	89·5	18	1·57
,,	12·30	102·0	9	1·88

(1) Obtained from tables due to Marvin (1915).

In the summaries of South African meteorological data (Union Department of Irrigation, Meteorological Office Reports, 1925-1934) values for relative humidity are given only for readings taken at 8.30 a.m., S.A.S.T. Since for ecological purposes the low midday humidities are probably of more significance than the higher morning values (Dyer 1937, p. 54; Bayer 1938, p. 383), it is suggested that more meteorological stations in South Africa should be encouraged to take readings at midday as well as in the morning.

SUMMARY.

A short summary is given of values of morning and midday relative humidities at Pietermaritzburg during the period 1st June, 1937, to 31st May, 1938. There is usually a marked fall in relative humidity at midday, this fall may or may not be accompanied by changes in the actual amount of water vapour present in the atmosphere.

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South African Journal of Science, *Vol. XXXV, pp. 158-161, December, 1938.*

A CONDUCTIVITY METHOD FOR THE ESTIMATION OF SOIL WATER MOVEMENT II — OBSERVATIONS ON THE SOIL *IN SITU.*

BY

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With 2 Text Figures.

Read 5 July, 1938.

In an earlier paper, the writer (1936) gave an account of an electrical conductivity method for the estimation of the depth and rate of penetration of water into the soil. The present note describes the application of this method to the study of soil water movements in the grounds of the Natal University College, Pietermaritzburg, from the beginning of the rains in the latter half of 1937 until the return of the normally dry winter weather in May-June, 1938.

A set of twelve electrodes was buried in June, 1937, at the edge of an ungrassed path near the Physical Chemistry laboratory, and leads were brought through an opening in the wall, and through the floor, to the conductivity bridge. The site was slightly screened by the building, so that the rainfall recorded by an adjacent rain-gauge was somewhat lower than that received by a normally exposed gauge, but the results obtained from the latter, and quoted by Bayer and Coutts (1938), represent the general nature of the seasonal variation to which the site was exposed. For the latter half of the period, a recording rain-gauge was constructed in order to obtain indications of the intensity of the rainfall.

Calling the electrodes A, B, C, . . . K, L, the depths to which they were buried below the surface were as shown in Table I Thus, a change in conductivity measured between the

Table I—Depth (in inches) of Electrodes Below the Surface.

A	1·9	E	4·9	I	7·7
B	2·6	F	5·7	J	8·4
C	3·5	G	6·4	K	9·2
D	4·5	H	7·1	L	9·6

electrode pair AB represented a penetration of moisture to a depth of 2·6 inches, and the lowest depth at which records were

obtainable (for the electrode pair KL) was 9·6 inches. (It is hoped to arrange for readings at greater depths during the coming season.)

In the course of the season, some thousands of conductivity measurements were obtained, but it is unnecessary to give a detailed account of the observations here. The general nature of the results is sufficiently well indicated by the diagram (Fig. I), which shows the conductivities for the electrode pairs AB, BC, . . . KL for the period September 1937 to May 1938 (above) and the rainfall in inches (below). The time scale on this diagram is too small to show certain points if interest, but these will be described later. A number of general features can, however, be discussed by reference to Fig. I.

Apart from a few light showers, the first moderately heavy rain of the season occurred on 19th September, 1937, when there was a fall totalling 0·42 inches, but this failed to penetrate beyond a depth of 2·6 inches in the dry soil, as is shown by the " hump " in the curve for the electrode pair AB, and the absence of any effect for the other electrodes. This fall occurred in the form of a number of light showers in the morning, and a few heavier showers in the evening. Showers on 30th September, 1937 and a slight storm on 2nd October, 1937 had no appreciable effect. Heavier rain, totalling 0·43 inches on the afternoon of 5th October, 1937 and morning of 6th October, 1937 followed by lighter rains on the two following days ultimately penetrated 4·9 inches, the effect being just appreciable at the electrode pair EF. Even allowing for the moistening of the soil by the intervening light rains, the increased effect of continuous rain (5th October, 1937) as compared with intermittent showers giving the same aggregate (19 September, 1937) is notable. The first case of penetration to the maximum depth of 9·6 inches occurred on 6th November, 1937, after a storm in which there was a precipitation of 0·19 inches in half an hour, followed by light showers.

The details just given for the first section of the record should make it simple to interpret the remainder of the diagram. It will be seen that the heavier rains during the summer months all had appreciable effects down to 9·6 inches. The falling off in conductivity during dry periods provides an estimate of the rate of decrease of mobility of soil moisture. The decrease was fairly rapid during the hot season, but at no time before the return of winter conditions in May-June, 1938, did the conductivity fall quite as low as the initial values for September, 1937.

The examples quoted above show that when the soil is dry a rainfall of about half an inch is necessary to penetrate effectively to a depth of 5 inches. As might be expected, smaller amounts are effective if the soil is already moist, for the addition of these smaller amounts is then sufficient to provide a supply of " free " water in the soil. For instance, when the soil was

already moist, a shower of short duration on 5th January, 1938, producing 0·23 inches of rain, gave an appreciable effect to a depth of 7·7 inches. Again, after the storm of 27th February, 1938, had penetrated at least 9·6 inches, the intermittent rains between 6th March and 9th March, 1938, were effective to 7·1 inches; but after a hot and dry period of twelve days, the storm on 18th March, 1938, which yielded 0·63 inches of rain affected the mobility to a depth of only 5·7 inches—a result in reasonable agreement with the observations at the commencement of the season in early October.

The experiment was concluded for this season when the electrodes were unburied on 18th June, 1938, and the moisture contents of the sections of soil between the electrode pairs were determined by oven-drying at 102°C. The conductivities at this stage had fallen to very low values, and the results obtained for the moisture contents give an estimate of the immobilised water held by the soil.

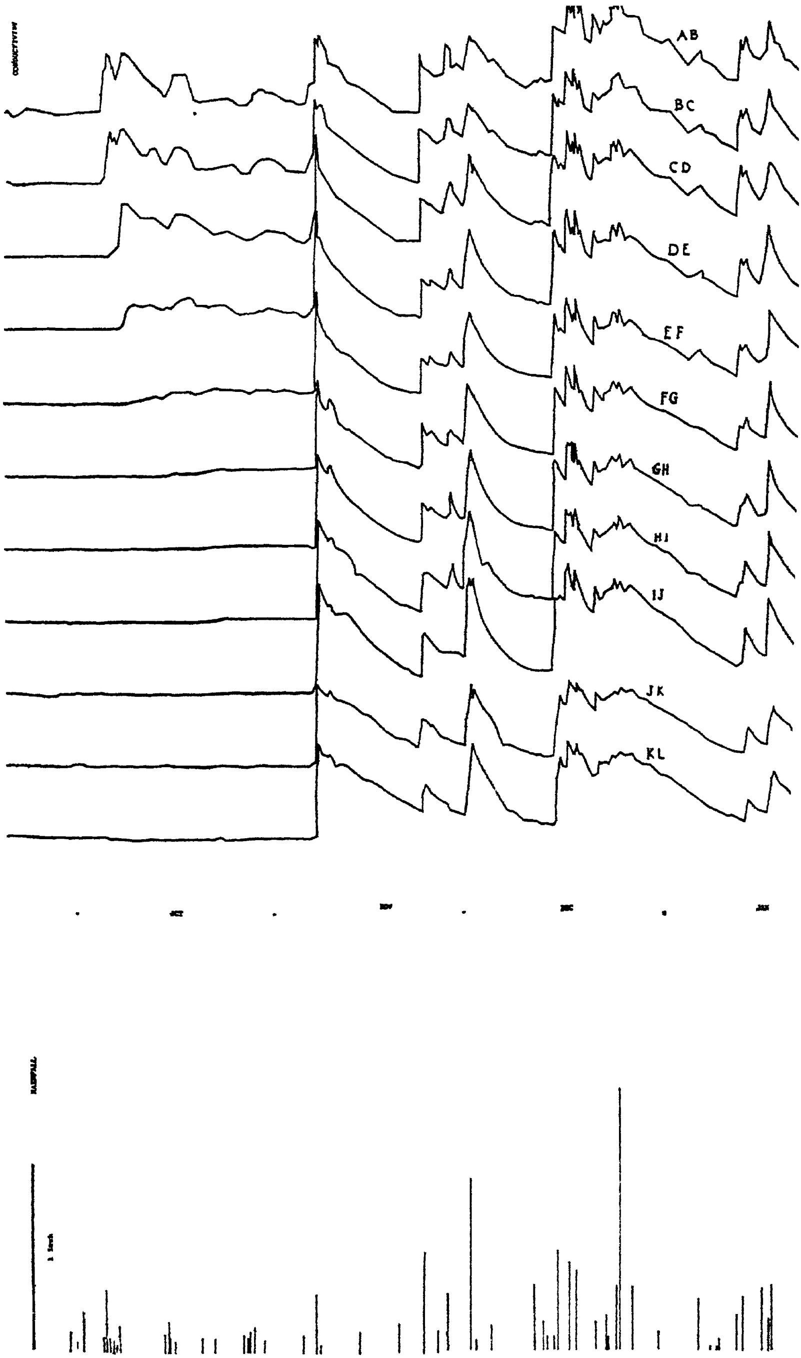
TABLE II—Percentage Moisture Contents of Soil Sampled Between Electrodes (18-6-38).

AB	16·0	EF	18·4	IJ	19·9
BC	17·6	FG	19·2	JK	22·6
CD	17·8	GH	19·5	KL	21·8
DE	18·4	HI	19·7		

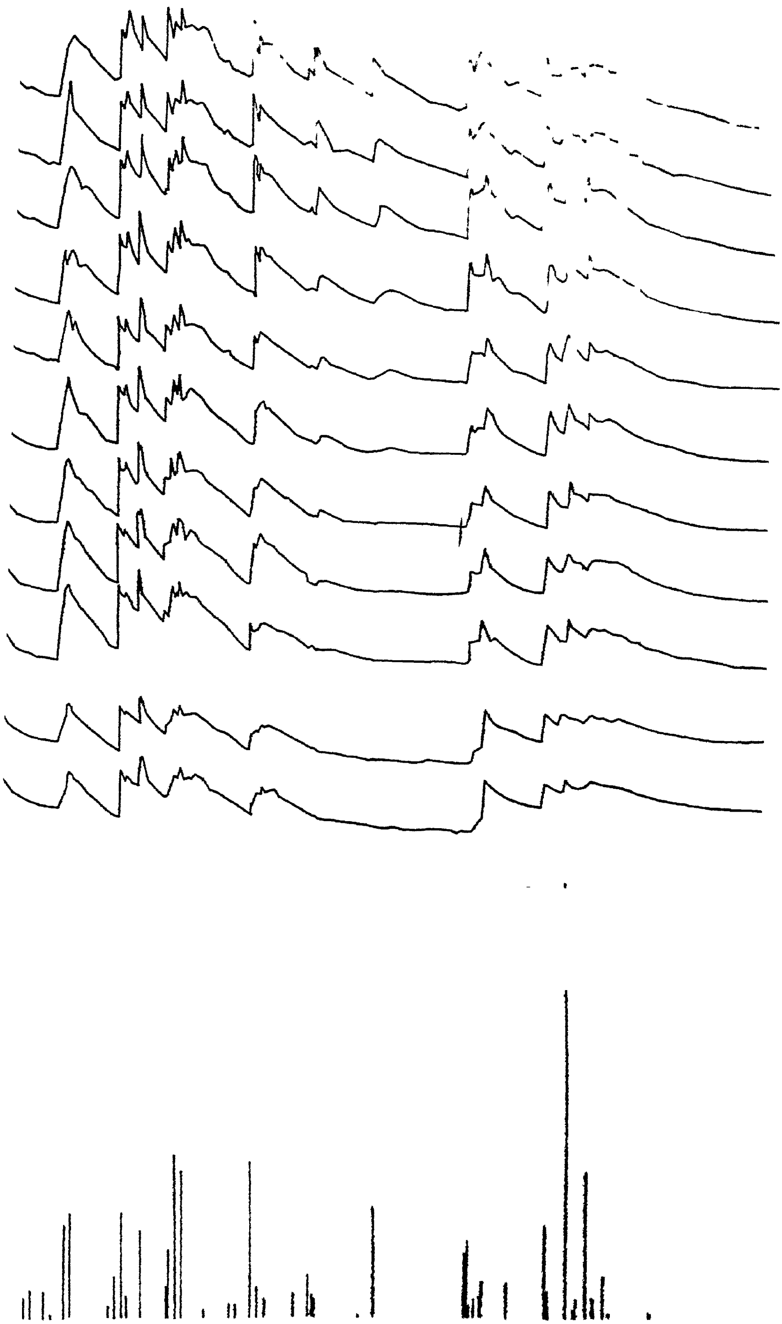
(Note.—The wilting coefficient, calculated from the moisture equivalent by Briggs' formula, is approximately 13 per cent for soil in the N.U.C. grounds.)

The ordinates in Fig. I give the conductivities in ten-thousandths of reciprocal ohms, but these absolute values, and the actual values of the maxima are of little significance for the present purposes; some of the reasons for this were discussed in the earlier paper, cited above. In addition, the rapidity with which the conductivity fell below the maximum value must be taken into consideration. Many of the storms occurred in the late evening, and it was not always possible to take readings until an hour or more after the commencement of the storm. The most important case to which this applies was that of the exceptionally heavy storm on 17th April, 1938, when 2·4 inches of rain fell between 18h. and 18h., 40m., but readings could not be taken until 19h., 40m., when a relatively low peak was found for the maximum in the uppermost electrode pair. The readings did, however, serve to show that the rain had penetrated as far as 9·6 inches within the period from 18h. to 19h., 40m.

In some cases, readings were taken during actual storms, and estimates of the rate of penetration could then be made by noting the times at which sudden increases in conductivity occurred at the depths of the various electrode pairs. The results naturally vary considerably with the intensity of the rainfall, but one example is shown in Fig. II. This diagram refers to the

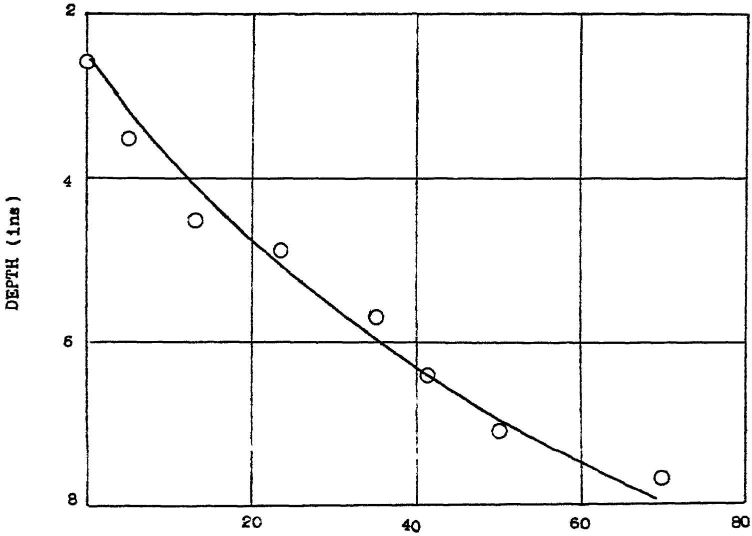


Fig



. I.

To face page 100



TIME (mins.)

Fig. II.

storm on 27th February, 1938, when 0·87 inches of rain fell in rather less than three hours, about 90 per cent. of the fall occurring in the first hour of the storm. The curve shows the trend of percolation from electrode B downwards as far as electrode I; from Fig. I, it may be seen that the rain ultimately penetrated to electrode L.

SUMMARY.

An account is given of measurements made in a study of the variation of the soil moisture conditions in the Natal University College grounds from September, 1937 to June, 1938.

The writer wishes to express his thanks to Prof. O. J. P. Oxley for the preparation of Fig. I.

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NOTE ON EDDINGTON'S JUSTIFICATION OF THE METHOD OF LEAST SQUARES

BY

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With 3 Text Figures.

Read 5 July, 1938.

1. Introduction.

In 1933 Eddington (1) wrote a paper "to controvert two rather prevalent ideas." We are concerned here with the first of them, namely, the idea "that the method of least squares is only justified if the errors of observation have a Gaussian distribution."

Of the many approaches that have been made to the theory of least squares, the majority are based either on this assumption of a normal frequency distribution in the errors of observation, or on some other assumption which in turn implies the normal frequency distribution. Some have been content to regard this distribution as a satisfactory empirical law. Others have sought to explain it by supposing that the error in each single observation is itself caused by the superposition of a large number of smaller errors.

This assumption of a normal distribution of observations has been a favourite target for the critic. If we exclude cases where constant or systematic errors are appreciable, and confine attention to cases where accidental or random errors are predominant, it is still not safe to assume that these random errors will always have, ultimately, a normal distribution. Eddington points out that a widely prevalent cause, namely, heterogeneity of observational material, tends to produce a systematic deviation from the normal distribution. For instance, the data obtained by different observers of different skill, or the data obtained by the same observer working under varying conditions, may be expected to have errors with a distribution differing from the normal. There will be more large and more small errors, balanced by less errors of intermediate size. Then again there are experiments in which, even when performed under the most constant and ideal conditions, we expect the errors of the observations to have ultimately a non-normal distribution. (2)

Thus far the critic. Eddington's reply is to show that the method of least squares is justified even when the observer does not produce normally distributed observations. If the calculator uses the method of least squares in combining the observations, then *he* combines a lot of little independent errors, and *he* creates a frequency distribution closely approximating to the normal. This fact justifies his method.

The argument applies to problems in any number of unknowns. An application to a simple example in one unknown, however, may help to clarify the idea. Suppose that we have 30 observations of a quantity and that their arithmetic mean is 224. Suppose we know also that if a great many observations were made their root mean square error would ultimately be 7. The theory of least squares shows that with a risk of 1 in 2 we may assume the true value of the observed quantity to lie within the range or "confidence interval"

$$224 \pm \tfrac{2}{3} \times 7/\sqrt{30}.$$

The second term is the probable error, and the statement means that if we repeat a great many sets of 30 observations and make a similar judgment for each one, we shall in the long run be right and wrong equally often. A more useful judgment is that with a risk of 1 in 20 we may assume the true value of the observed quantity to lie within the interval

$$224 \pm 2 \times 7/\sqrt{30}.$$

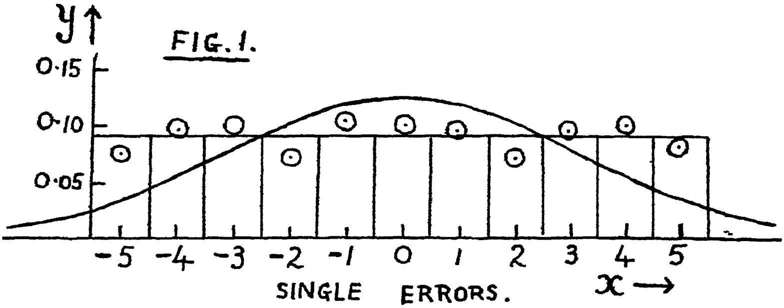
Eddington's justification of these estimations lies not in assuming that the ultimate distribution of thousands of observations would be normal, but in pointing out that the distribution of thousands of arithmetic means each calculated from a random set of 30 observations would be normal—or, rather, would closely approximate to the normal. This is because the error in each mean is itself the sum of 30 small independent errors. The distribution approaches closer and closer to the normal as we consider not just 30 observations, but a great many more. A full discussion involves theorems due to Laplace, Liapounoff, and others. (3)

2. The Effect of Having Only a Few Observations.

When we consider practical cases, the number of observations, n, is never indefinitely large, and is sometimes small. In the above example, $n = 30$. We may ask whether 30 is large enough to justify the assumption that the arithmetic means have an ultimate normal distribution. Eddington has answered without proof or comment that $n = 6$ or 8 is sufficient to give a good normal curve.

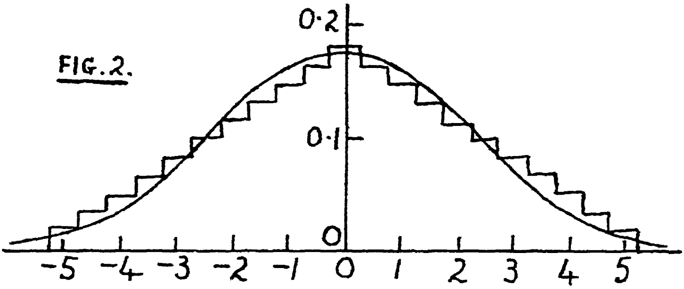
Our aim here is to test this claim in a particular case. We have chosen a discontinuous set of possible errors, namely, the eleven numbers $5, 4, 3 \ldots . -5$. The restriction of the possible errors to a discrete set of values should not be regarded as a mere convenient simplification. For errors of observation always have their values restricted in this way. We suppose

FIG. 1.



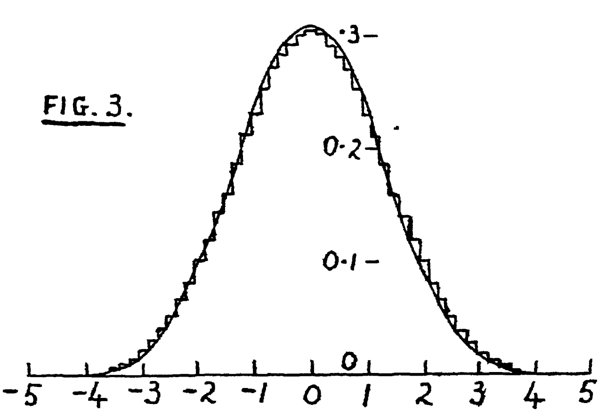
SINGLE ERRORS.

FIG. 2.



ERRORS IN MEANS OF 2.

FIG. 3.



ERRORS IN MEANS OF 6.

the probability of obtaining any one of these errors at a single observation to be 1/11. They occur, therefore, with an ultimate frequency distribution described by the rectangle of Fig. 1. The rectangle consists of a set of steps, in this case all of equal height. The area under each step is the probability of finding the error represented by the centre of the step. In the same figure is shown the corresponding normal error curve, chosen so as to have the same standard deviation. This curve represents a continuous distribution of errors such that ydx is the probability of finding an error between x and $x + dx$. It will be noticed that the errors have a distribution anything but normal.

We then consider the arithmetic means of random pairs of such errors. The possible values of such means are the twenty-one numbers 5, $4\frac{1}{2}$, 4, $3\frac{1}{2}$ . . . . − 5. These occur with an ultimate frequency distribution described by the stepped curve of Fig. 2. Again the corresponding normal curve is shown for comparison. In this case it is noticed that the centres of the steps form a triangle fitting roughly over the normal curve.

In a similar way, considering the means of random groups of n errors, we have compared their distributions with the corresponding normal distributions not only for $n = 1$ and 2, but also for $n = 3, 4 \ldots 8$. We find that when $n = 3$ the normal distribution has already become a good approximation for the actual distribution. The comparison for $n = 6$ is shown in Fig. 3, and fully justifies Eddington's claim.

The closeness of the approximation may be shown in another way. We imagine a set of n observations of an unknown, m being the arithmetic mean of the set, and σ the ultimate standard deviation. With any given risk we may estimate the value of the unknown as lying within a corresponding confidence interval. When the errors have a *normal* distribution, this interval is known to be

$$m \pm a\,\sigma/\sqrt{n}, \qquad . \quad . \quad . \quad . \quad . \quad (1)$$

a being a known function of the risk. (Three values of a are shown in Table I.) When the errors have the *rectangular* distribution of Fig. 1, we have a different interval, which we may write as

$$m \pm f\,a\,\sigma/\sqrt{n}, \qquad . \quad . \quad . \quad . \quad . \quad (2)$$

f being a correction factor. Some values of f have been computed and collected in Table I. The method of computing is explained in Section 4.

The values of f shown in the table are surprising in several ways. The closeness with which they cluster around the value 1 indicates that Eddington's claim for $n = 6$ or 8 is unnecessarily cautious. Even for $n = 2$ the confidence intervals calculated according to the method of least squares (i.e. with $f = 1$) are for practical purposes reasonably good approximations to the true intervals. Then, again, very few of the values exceed 1, while many are less than 1. This indicates that the

confidence intervals calculated by least squares tend to be not too small but unnecessarily large.

TABLE I.—THEORETICAL VALUES OF f.

Risk	1 in 2	1 in 20	1 in 100		1 in 2	1 in 20	1 in 100
a	·6745	1·96	2·58				
$n=1$	1·41	0·81	0·61	$n=6$	0·96	0·99	0·95
2	0·99	0·91	0·87	7	1·00	0·98	0·97
3	1·08	1·02	0·92	8	1·00	0·97	0·95
4	0·94	0·97	0·92	∞	1	1	1
5	1·04	1·01	0·93				

It will be noticed that for any given risk the sequence of values of f corresponding with increasing values of n presents a somewhat random appearance. There is a progressive approach towards the value 1, but superimposed on this is a different effect, due to the restriction of the possible errors to a discrete set of values. For example, when $n = 3$ we may expect any single average error to lie within the limits $\pm 3\frac{2}{3}$ with a risk of 1 in 19, and within the limits ± 4 with a risk of 1 in 33. When the risk allowed is 1 in 20 the limits have still to be taken as ± 4, since no values of the average error can occur between $3\frac{2}{3}$ and 4. This effect accounts for the "somewhat random appearance."

3. A Practical Check on the Foregoing Theory.

For the sake of interest we have made 1,000 observations of errors whose ultimate frequency distribution we expect to be the rectangle of Fig. 1. This has been done by tossing a dice and a coin together 1,000 times. The numbers 1 to 5 were recorded as they fell, being regarded as positive if associated with a head, and negative if associated with a tail. The number − 6 was recorded as zero, while − 6 was always disregarded. This gave an equal *a priori* probability of recording any one of the eleven numbers 5, 4, 3 . . . . − 5. Their frequency of occurrence divided by 1,000 is shown as a probability in Fig. 1. The *a priori probability* with which we expect a given error equals the area of the appropriate step in the rectangle. The *observed probability* equals the area of the same step when its top is raised or lowered to the appropriate encircled point.

Taking the 1,000 observations in the order in which they were recorded, we have grouped them into 500 successive pairs,

into 250 successive sets of four, and into 125 successive sets of eight. In this way we have computed the observed probability of finding any given error in a single arithmetic mean of two observations, in a single mean of four observations, and in a single mean of eight observations. From these, as explained in Section 4, we have computed some "observed values" of the correction factor f. These values are collected in Table II. Their close agreement with the *a priori* expected values in Table I is at once a confirmation of the theory, a check on the computations, and an additional support for our conclusions.

TABLE II.—OBSERVED VALUES OF f

Risk	1 in 2	1 in 20	1 in 100
$n=1$	1·41	0·81	0·61
2	0·99	0·91	0·87
4	1·17	0·97	0·98
8	1·00	0·97	1·08

4. How the Figures and Tables are Computed.

A variable error x can take on any one of the 11 values -5 . . . 0 . . . . 5, all of which occur in the long run equally often.

Considering first this distribution of single observations of x, we may represent it symbolically by the probability array (4):—

$$f(t) = (t^{-5} + t^{-4} + \quad . \quad . \quad . + t^{4} + t^{5}) / 11$$
$$= \frac{1}{11\,t^{5}} \left(\frac{1 - t^{11}}{1 - t} \right) . \qquad . \quad . \quad . \quad (3)$$

In this polynomial in t the coefficient of t^{x} is seen to be equal to the probability p_x that at a single observation we shall find the error x. In other words, we may tabulate the values of p_x for various values of x as follows:—

x =	−5	−4	−3	−2	−1	0	1	2	3	4	5
$11\,P_x$ =	1	1	1	1	1	1	1	1	1	1	1

This distribution is represented graphically by the rectangle of Fig. 1.

The ultimate mean square of x is $\Sigma x^2 / 11 = 10$. The normal error curve in Fig. 1 is therefore the curve

$$y = \left(2\pi\sigma^2 \right)^{-\frac{1}{2}} e^{-x^2/2\sigma^2}, \qquad . \quad . \quad . \quad (4)$$

where σ^2 has the value 10.

Proceeding to the distribution of the variable

$$u = \tfrac{1}{2}(x_1 + x_2),$$

we have the corresponding probability array

$$[f(t^{\frac{1}{2}})]^2 = \frac{1}{11^2 t^5}\left(\frac{1 - t^{11/2}}{1 - t^{\frac{1}{2}}}\right)^2 \quad . \quad . \quad (5)$$

In this array the coefficient of t^u is equal to the probability p_u that for a single pair of random observations of x, their arithmetic mean will take the value u. The expansion of equation 5 by the binomial theorem gives the following distribution for p_u:—

u	=	-5	$-4\frac{1}{2}$	-4	$-3\frac{1}{2}$	-3	$-2\frac{1}{2}$	-2	$-1\frac{1}{2}$	-1	$-\frac{1}{2}$	0
$11^2\ P_u$	=	1	2	3	4	5	6	7	8	9	10	11
u	=	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	
$11^2\ P_u$	=	10	9	8	7	6	5	4	3	2	1	

This distribution is represented graphically by the stepped curve of Fig. 2.

Since the ultimate mean square of x is 10, the mean square of u is given by a standard theorem (5) as 5. The normal curve in Fig. 2 is therefore given by equation (4), where σ^2 has the value 5.

Proceeding to the general case of the distribution of the variable $v = (x_1 + x_2 + \ . \ . \ . \ . + x_n)/n$, we have the corresponding probability array

$$[f(t^{1/n})]^n = \frac{1}{11^n t^5}\left(\frac{1 - t^{11/n}}{1 - t^{1/n}}\right)^n \quad . \quad . \quad . \quad (6)$$

In this array the coefficient of t^v is equal to the probability p_v that for a single set of n random observations of x, their arithmetic mean will take the value v. By an expansion of equation (6) by the binomial theorem and by the use of tables (6) of ${}^nC_r$, these distributions were computed for the cases $n = 3$, 4, 5, 6, 7 and 8. The distribution for the case $n = 6$ is represented graphically by the stepped curve of Fig. 3.

The ultimate mean square of v is found as before (5) to be $10/n$. The normal curve in Fig. 3 is therefore given by equation 4, where σ^2 has the value of $10/6$.

To indicate the integration process by which the values of f were obtained for Table I, we show here how a particular value was computed, viz., $f = 0{\cdot}92$ for $n = 3$ at a risk of 1 in 100. The above distributions showed that for $n = 3$ the probability of finding $v = 5, 4\frac{2}{3}$, or $4\frac{1}{3}$ is $\cdot 00075$, $\cdot 00225$, and 00451 respectively. The same probabilities apply to the values $v = -5, -4\frac{2}{3}$, and $-4\frac{1}{3}$. Addition then shows that the probability of finding v numerically greater than 4 is 1 in 67, while the probability of finding v numerically greater than $4\frac{1}{3}$ is

1 in 167. If we are prepared to take a risk of 1 in 100, we may therefore assume that v lies within the inclusive range $\pm 4\frac{1}{3}$. On the other hand, the application of the method of least squares in the form of equation 1 gives the range $\pm 2{\cdot}58 \sqrt{10}/\sqrt{3} = \pm 4{\cdot}71$. Hence $f = 4\frac{1}{3} \div 4{\cdot}71 = 0{\cdot}92$.

In a similar way the values of f in Table II are obtained.

5. Summary.

Eddington showed that the method of least squares is justified not only for observations with an ultimate normal distribution, but also for observations with a non-normal distribution, provided that a sufficient number of observations is made. It has been shown here in the case of a particular non-normal distribution that the confidence intervals calculated by the method of least squares are surprisingly accurate even when the number of observations is as small as three.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 170-172, December, 1938.*

NOTE ON THE SETTLING OF THE PARTICLES OF A COLLOIDAL SOLUTION

BY

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Read 7 July, 1938.

The particles of a colloidal solution are often of a density greater than that of the surrounding liquid. We should expect them to settle to the bottom of the containing vessel. In some cases such settling is observed during the course of, say, a few days; we generally call these liquid systems *suspensions*. But in a colloidal solution proper the particles may remain uniformly distributed for months or years. We recognise the contrast as arising from a difference in particle size. The particles are larger in suspensions than in colloidal solutions. It has often been thought that in colloidal solutions the maintenance of a uniform distribution is due to the rapid Brownian movement of the small particles aided by the mutual repulsions of the electric charges on the particles.

It is certain, however, that the persistent uniformity of a colloidal solution is not to be explained in this way. It is rather the result of convection currents. In ordinary conditions the normal temperature variations in the atmosphere are sufficient to bring about such currents. Settling occurs if precautions are taken to keep the temperature as uniform as possible.

In 1932 McDowell and Usher published an account of an experiment they carried out with colloidal gold. "A red gold sol made by Zsigmondy's formaldehyde method was enclosed in a glass tube 4 cms. long and of 7 mms. bore, which was sealed and suspended in water contained in a large silvered cylindrical vacuum vessel." On other occasions the tube of gold sol was placed in the centre of a one-pound roll of cotton wool. When examined after a few days, settling of the colloidal solution could be observed. After a few weeks the settling was very marked, the colloidal gold having collected in a deep-coloured layer at the bottom of the tube. When the tube was withdrawn and left exposed to the air, mixing began almost immediately and continued until the gold was once more uniformly distributed throughout the liquid.

The object of this Note is to describe a repetition of these experiments in which ordinary 25 c.c. Jena glass stoppered bottles were used to contain the colloidal solutions. Two sols were tested, one a gold sol prepared from gold chloride solution by the addition of a few drops of a solution of phosphorus in ether, and the other a copper oxide sol prepared by Bredig's method of an arc discharge between copper electrodes in distilled water.

In one case the bottles containing the sols were lowered into water in silvered Dewar vessels as described by McDowell and Usher. During the following month the bottles were examined on several occasions. The colloidal matter gradually settled.

The main observations, however, were made on bottles wrapped in cotton wool for long periods. The experiment was started in 1934. The same specimens of gold and copper were so wrapped up on three successive occasions, being left to stand for 9 months, 4 months and 17 months in turn. When the bottles were examined after each of the first two periods of standing, considerable settling had occurred.* The greater part of the liquid was left with a very pale colour, most of the colloidal matter being located in the lowest few millimetres of the liquid column. When these bottles were left exposed to the air, the colloidal matter gradually spread uniformly throughout the liquid.

After the last and longest period of standing a good deal of coagulation had taken place, possibly as the result of slow contamination from the glass. (Some of the same copper oxide sol prepared in 1934 and put away in *quartz* bottles showed no coagulation.) In each case, however, a little of the material was still in the colloidal state, and the upper liquid soon darkened in colour after the removal from the cotton wool just as it did on the previous occasions.

The liquid containing a large amount of colloidal matter is denser than the solvent. Hence large and sudden temperature changes (as would be imposed, for example, by deliberately heating the bottle) would be required to cause the concentrated layer at the bottom of the bottle to rise. Suppose, however, that very feeble convection currents are set up in the almost uniform (nearly clear) liquid on top; these currents will skim along the surface of the denser portion, and in so doing will detach small amounts, very thin layers or wisps, of slightly denser liquid, especially since the change in density as we descend, though sudden, is strictly gradual. The colloidal matter will be carried up a bit at a time and mixed with the upper liquid. This detachment of denser material was frequently

* After the second period, in 1936, when the wrappings were removed, the bottles were shown to Section A at the Johannesburg Meeting of the Association.

seen to be taking place in these experiments. It showed very clearly and convincingly that convection currents were actually present. Further, the thickness of the dense layer gradually diminished.

A deepening of the colour of the upper portion of the liquid was easily detected after one day's exposure to ordinary conditions. In the case of the gold sol the dark layer at the bottom had disappeared entirely in three to four weeks, and then the liquid appeared to be quite uniform. In the case of the copper oxide sol, a period of two to three months was required for the attainment of complete uniformity.

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NOTE ON A MODIFICATION OF RAYLEIGH'S RIPPLE METHOD FOR THE MEASUREMENT OF SURFACE TENSION

BY

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(*With Demonstration*).

Read 5 July, 1938.

FIFTY YEARS AGO—THE DISCOVERY OF ELECTRO-MAGNETIC WAVES BY HERTZ

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NOTES ON THE POLYPHASE VARIABLE SPEED COMMUTATOR MOTOR

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With 6 Text Figures.

Read 7 July, 1938.

1.—INTRODUCTION.

The almost universal use of three-phase alternating current systems for transmission and distribution of electrical energy can be attributed, to a very large extent, to the simplicity and robustness of the induction motor. With this simplicity is coupled a serious disability, namely, a lack of efficient speed regulation. It is possible to reduce the speed of an induction motor by inserting resistance in the rotor circuit, by changing the number of poles or by cascade connections. The first method gives a series characteristic to the motor, and the latter two methods do not allow of continuous speed variation, the speed being reduced in steps.

The first really serviceable motor, with continuously variable speed control, and with a shunt characteristic, was produced in 1911 to the designs of H. K. Schrage. The machine is fitted with two movable brush sets connected to separate stator phases, power being supplied through slip-rings to the rotor, while a special regulating winding is employed as the commutator winding. The addition of the commutator raises the frequency of the slip energy to the frequency of supply, and thereby enables this energy to be taken from, or returned to, the supply lines, according to whether the speed is above or below synchronism. Thus, the range is not confined to sub-synchronous speeds, as in the induction motor. Commutation difficulties limit the speed range.

The characteristic features of the Schrage Motor are:—

1. The motor can be started without rheostats by switching in the motor on the line with the brushes in the start position, when the motor immediately accelerates to about one-third maximum speed. With one and a half times normal full-load current the motor gives a starting torque of about one and a half times full-load torque for non-reversible motors and full-load torque for larger reversible motors.

2. Continuous speed regulation is secured by the simple operation of shifting the brushes while the machine is on load.

3. The speed can be regulated from half synchronous speed to one and a half times synchronous speed.

4. The motor has shunt characteristics.

5. The motor gives constant torque at any speed; the horsepower output is, therefore, proportional to the speed.

6. High overall efficiency.

7. The power-factor can be varied at will by brush-axis displacement.

2.—General Theory.

In the ordinary induction motor, working at constant torque, the loss of output due to speed reduction has a value equal to the extra loss in the rotor circuit due to the insertion of the regulating resistances. Such a method of speed control is wasteful, and only allows of a variation below synchronism. The obtaining of speeds above synchronism entails the supplying of energy to the rotor circuit to balance the increase in output due to supersynchronous speed.

In the Schrage motor speed variation above and below synchronism is obtained by transferring energy to or from the rotor, this is accomplished by the use of a commutator winding. E.m.fs. of the same frequency as those induced in the stator are obtained from the commutator making the transference possible.

There are outstanding differences between resistance control and energy-transference control; in the former speed varies greatly with load; in the latter load makes little difference to speed, by suitable brush adjustment both speed and power-factor can be given any desired values within the range of the machine. Furthermore, the machine can be made to take a leading current, thus assisting power-factor correction in the supply system.

A diagrammatic sketch of a three-phase, two-pole Schrage motor is given in Fig. 1. The machine has a primary winding on the rotor which is fed from the supply mains through slip-rings. The secondary is on the stator and the ends of each phase are brought out to terminals. In the same rotor slots as the primary there is a regulating winding (hereinafter called a commutator winding), which is, in reality, a direct current lap winding connected to the secondary through six brush-halves, fixed to two brush-rockers, three on each spaced 120° apart, the beginnings of the secondary windings are connected to the brushes on one rocker and the ends to those on the other rocker. These rockers are capable of being moved relative to one another and relative to the stator. Thus the brush-axis as well as the brush-spread is variable.

If the secondary be disconnected from the brushes and a suitable three-phase voltage impressed upon the primary, a rotating field will be produced, and a voltage of supply frequency

will be induced in the secondary. Let the rotor be rotated against the flux: then the magnitude of the secondary induced e.m.f. will be a function of the difference between the frequencies of rotation of the flux and rotor, and its frequency will be equal to this difference, i.e., will be equal to the frequency of slip.

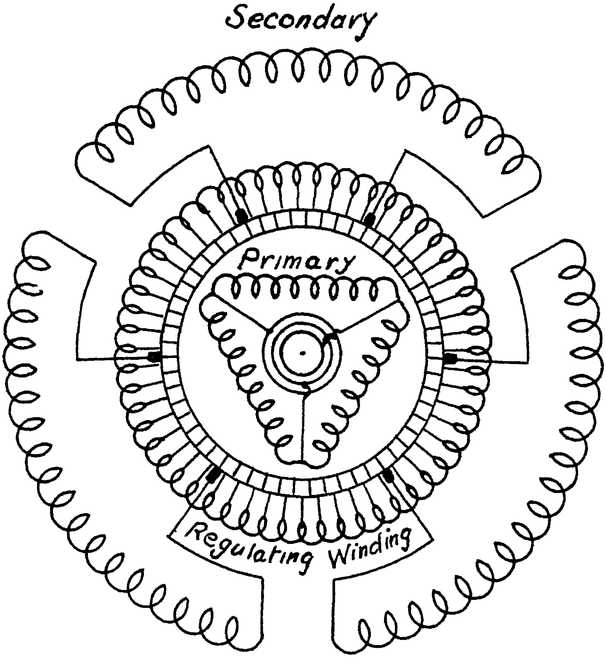


Fig 1

The rotating field cuts the commutator winding conductors at synchronous speed; thus the e.m.f. generated in any one conductor of the commutator winding is constant, the magnitude of the e.m.f between the brush-halves depends only upon their spread. The brush e.m.f. can, therefore, be altered in magnitude by moving the brush-rockers in opposite directions, and a change in sense can be obtained by crossing the pairs of brush-halves. The frequency of the e.m.f. in each commutator winding conductor will be equal to that of the supply, but the frequency of the e.m.f. between the brush-halves will be equal to the difference in the frequencies of rotation of rotor and flux, and thus always equal to that of the secondary e.m.f. Changing the brush-axis will not alter the value of the e.m.f. between pairs, but the phase difference between the commutator and secondary e.m.f. depends upon the position of the brush-axis. Thus the function of the commutator is to provide a constant e.m.f. of secondary frequency which can have any given phase relation to the secondary e.m.f.

Consider the secondary connected to the brush-halves and normal voltage impressed on the primary. The rotor will rotate at such a speed as will make the total e.m.f. acting round a secondary-brush circuit equal to the resistance and reactance drops. With pairs of brush-halves brought together the rotor speed is almost that of synchronism and the machine behaves as an ordinary induction motor. As the brush-spread is increased in one direction the speed will fall below synchronism, whilst if the spread is increased in the opposite direction the speed will rise above synchronism. Energy is always given to the secondary by transformer action from the primary. At subsynchronous speeds a further amount of energy is given to the secondary via the commutator and primary, whilst if the speed is supersynchronous a further amount of energy is given to the secondary via the primary and commutator combination. In the commercial machine the two brush rockers travel at different rates. By this means a better power-factor is obtained at subsynchronous speeds at the expense of the power-factor at supersynchronous speeds.

Successful commutation depends upon being able to design the motor so that the resultant e.m.f. in the short-circuited coil does not exceed a value which can be dealt with by the brush contact resistance. In some machines resistors are placed in the coil leads to assist commutation. The transformer e.m.f. generated in a short-circuited coil by the field flux is constant in magnitude and frequency, whereas the frequency of the e.m.f. between brush-halves depends upon the speed of the rotor. If the e.m.f. induced in each conductor has R.M.S. value e_c, then, assuming sinusoidal flux distribution, its maximum value will be $\sqrt{2}e_c$. The transformer e.m.f. in any short-circuited coil will vary between this value and zero, depending upon the relative positions of the flux wave and brush at the period of commutation. The induced e.m.f., $-L\frac{di}{dt}$, due to change of current, cannot be represented in the vector diagram since the periodic time of phase quantities is different from that of the time of commutation. However, since this e.m.f. is proportional to the change in current, it can be represented by a vector in the same direction as the secondary current.

3.—Mathematical Theory.

The following assumptions are made:—

(i) All currents and voltages vary harmonically with time.

(ii) The flux is distributed according to a sine law.

(iii) There is no appreciable leakage between the primary and commutator windings. The primary leakage reactance drop is, therefore, proportional to the vector sum of the primary and commutator ampere-turns. This is further simplified by assuming that the magnetising current is flowing in a coil in parallel with the motor and by neglecting the reactance and resistance drops due to it.

(iv) The secondary leakage reactance drop is proportional to the product of the stator ampere-turns and the slip.

(v) The R.M.S. magnetising current is constant in value.

Let the primary quantities per phase and the secondary quantities reduced to the primary be:—

E_1 = primary impressed e.m.f.,

I_1 = primary current,

r_1 = primary resistance,

x_1 = primary reactance,

g_0 = exciting conductance,

b_0 = exciting susceptance,

E = $I_0/(g_0 - jb_0)$ = back e.m.f. produced in primary by main flux,

E_c = primary value of commutator e.m.f. for a brush spread of 180°,

I_2 = primary current required to overcome secondary ampere-turns,

r_2 = secondary resistance (comm. winding + secondary),

x_2 = secondary reactance at supply frequency,

$x = x_1 + x_2$

$\alpha = \dfrac{\text{commutator e.m.f. for brush spread } \beta,}{\text{commutator e.m.f. for a brush spread of } 180°,}$

β = angle of brush spread,

δ = angular displacement of brush rocker,

s = slip of motor,

$k_1 = \dfrac{\text{primary induced e.m.f.,}}{\text{secondary o.c. e.m.f.,}}$

$\dfrac{k_1}{s} = \dfrac{\text{primary induced e.m.f}}{\text{secondary induced e.m.f.}}$ at all loads,

= true ratio of transformation of voltages,

$\dfrac{1}{k_1} = \dfrac{\text{primary current to overcome secondary amp. turns}}{\text{actual secondary current}}$ at all loads,

= true ratio of transformation of current.

Let R_2 = actual resistance of the secondary, and

X_2 = actual reactance of the secondary, then it can be shown that the Equivalent resistance of the secondary

$$= R_2 \times \frac{\text{ratio of transformation of voltage}}{\text{,, \quad ,, \quad ,, \quad ,, current}}, \text{ and}$$

that the Equivalent reactance of the secondary

$$= X_2 \times \frac{\text{ratio of transformation of voltage}}{\text{,, \quad ,, \quad ,, \quad ,, current}}.$$

In the Schrage Motor the tranformation ratios between the different windings are rather obscure. In drawing vector diagrams it is usual to take the transformation ratio between primary and secondary as unity. In an actual case, of course this ratio is not unity and all vectors in the secondary diagram must be transformed by means of this ratio in order to get true values. If

$$k = \frac{\text{brush e.m.f. for } \beta = 180^\circ}{\text{secondary o.c. e.m.f.}}, \text{ then } \frac{\alpha k}{k_1} E_c \text{ is the}$$

actual commutator e.m.f. for a brush spread of β°. To reduce the brush e.m.f. vector to its primary value it must be multiplied by $\frac{k_1}{\alpha k}$, and to reduce the secondary current vector to the primary circuit it must be multiplied by $\frac{1 \pm \alpha k}{k_1}$ when there is no brush-axis displacement.

In order that the mathematical treatment may be general the following sign conventions will be adopted:—

(i) α is positive when β is such that the secondary and commutator ampere-turns oppose and negative when secondary and commutator ampere-turns are in the same direction.

(ii) s. is positive for sub-synchronous speeds, and negative for super-synchronous speeds.

Fig. 2 (a) gives the vector diagram for a symmetrical brush position when the machine running at a speed below synchronism and α is taken as positive. Since the ampere-turns on rotor and stator are equal and opposite the primary leakage reactance drop will be proportional to the secondary ampere-turns, i.e. to I_2. The primary value of the secondary-brush circuit current is $I_2\ (1 - \alpha k)$, the primary resistance drop is, therefore, proportional to $I_2\ (1 - \alpha k)$.

Fig. 2 (b) gives the vector diagram for an unsymmetrical brush position in which the brush rockers have been displaced by an angle δ from the axis of the secondary winding. δ will be considered positive if it causes the brush e.m.f. to lag behind the primary supply pressure. With δ positive the commutator ampere-turns will lead the stator ampere-turns as shown in the diagram.

The equivalent circuit is obtained by an extension of the method used by the late Dr. C. P. Steinmetz for obtaining the equivalent circuit of a transformer. It consists in obtaining the equations of the apparatus and eliminating between them until an equation of the form $E = I\ f(z)$ is arrived at; the form of the impedance function $f(z)$ will indicate the equivalent circuit.

Let the brush rockers be displaced from the secondary axis by an angle δ.

Let $m = \alpha k \cos \delta_1$

$n = \alpha k \sin \delta_1$

$Z_1 = r_1 + jx_1$ = impedance of primary,

$Z_0 = \dfrac{1}{g_0 - jb_0}$ = exciting impedance,

Z_2 = impedance of secondary and commutator winding.

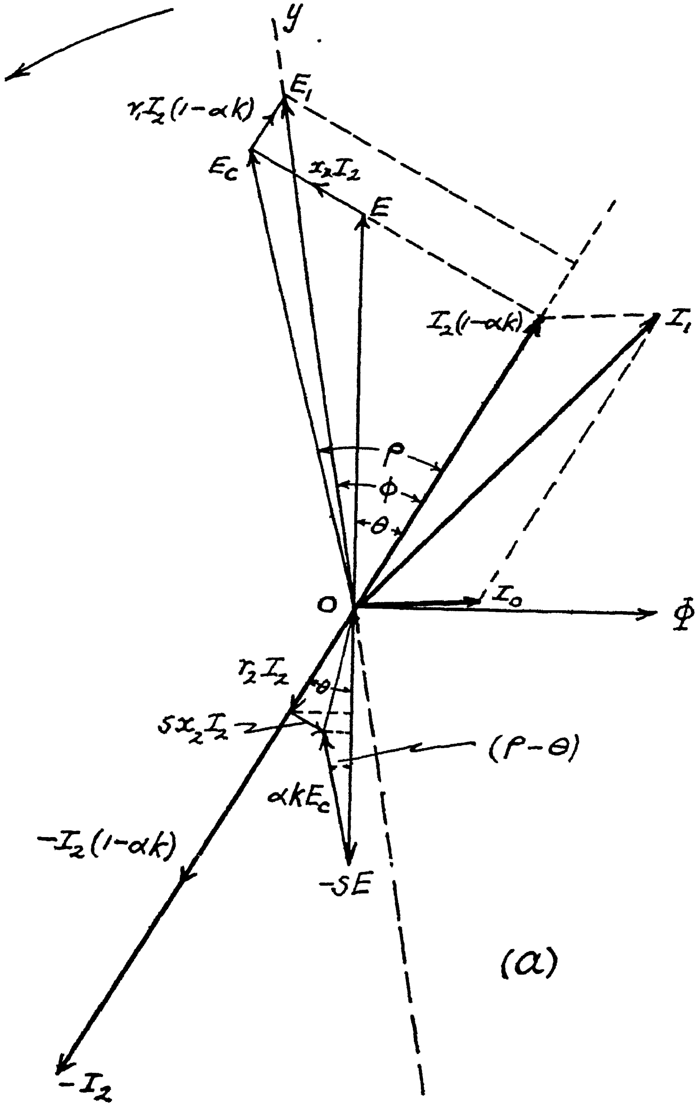


Fig. 2(a)

The current in the conductors of the commutator winding is not of slip frequency, but of line frequency. Therefore, its reactance at all speeds is x_c and $Z_2 = r_2 + j\,(sx_2 + x_c)$ where r_2 is the resistance of the secondary circuit (a variable quantity).

Due to brush axis displacement the ampere-turns of the commutating winding, which are proportional to $\alpha k I_2$, have a phase displacement of δ from the resultant primary ampere-turns.

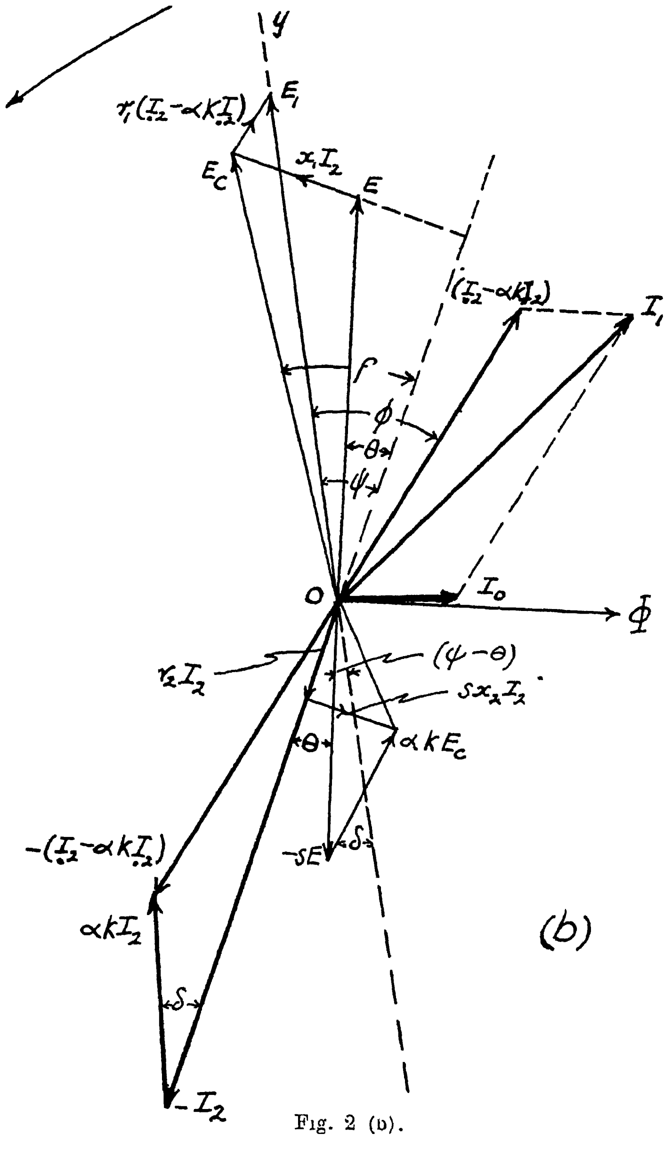


Fig. 2 (b).

The symbolic equations of the machine are:—

$$E_1 = Z_1 I_1 + E, \quad \ldots \ldots \ldots \quad (1)$$

$$I_1 = I_0 + I_2 \left(1 - \alpha k e^{j\delta}\right), \quad \ldots \ldots \ldots \quad (2)$$

$$I_0 = \frac{E}{Z_0} = (g_0 - jb_0)\, E, \quad \ldots \ldots \ldots \quad (3)$$

$$Z_2 I_2 = SE - \alpha k E \epsilon^{j\delta} = E\,(s - m - jn) \quad \ldots \quad (4)$$

From these equations it can be shown that the locus of the primary current vector is a circle of radius a_1, and whose centre is at the point (n_1, ξ_1), where O is the origin of co-ordinates and OE the axis of y, and where,

$$n_1 = \frac{E_1}{2}\left\{\frac{r_2\,(1 - m)}{mxr_1\,(1 - m) - r_2 x} + \frac{2n}{r_2}\right\}, \quad \ldots \quad (5)$$

$$\xi_1 = -\frac{E_1}{2}\,\frac{mx\,(1 - m)}{mxr_1\,(1 - m) - r_2 x}, \quad \ldots \ldots \quad (6)$$

$$a_1 = \frac{E_1}{2}\,\frac{1 - m}{mxr_1\,(1 - m) - r_2 x}\left[r_2^2 + m^2 x^2\right]^{\frac{1}{2}} \quad . \quad (7)$$

The radius and position of the centre of the current circle vary with α, and are, therefore, functions of the brush spread. The locus of the centre of the primary current circle is an ellipse whose centre is at $\left(\frac{E_1}{2x}, O\right)$, and whose semi-axes are $\frac{\alpha K E_1}{r_2}$ and $\frac{\alpha K E_1}{2r_2}$ inclined at an angle of 45° to the axes of co-ordination.

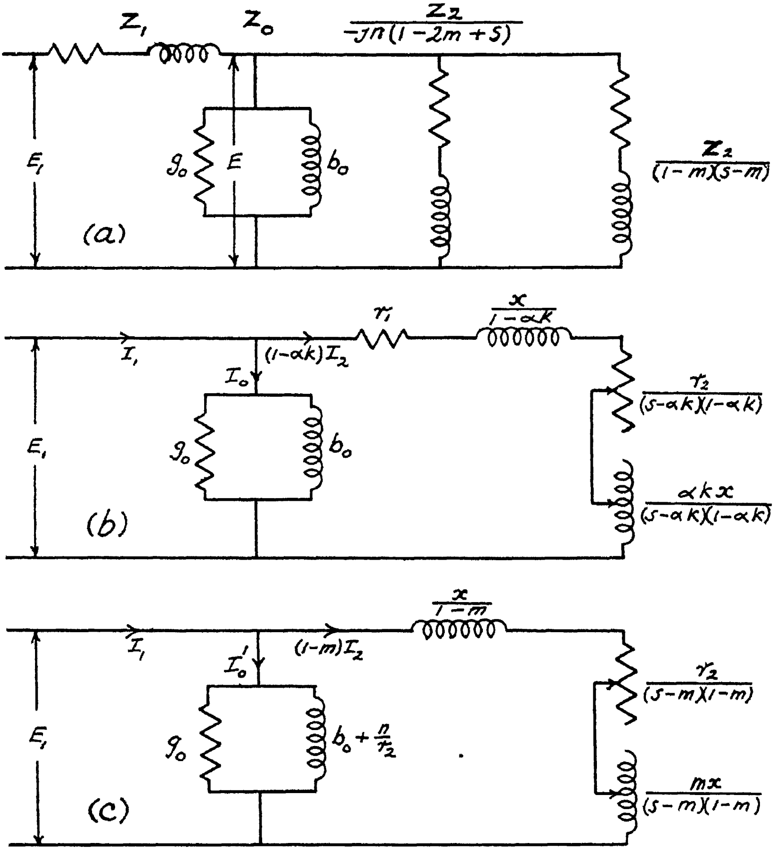
From equations (1), (2), (3) and (4) it can also be shown that the equivalent circuit consists of an impedance Z, in series with three impedances, Z_0, $\frac{Z_2}{(1 - m)(s - m)}$ and $\frac{Z_2}{-jn\,(1 - 2m + s)}$ in parallel. Neglecting certain small resistances the equivalent circuit is as shown in Fig 3 (a). Fig. 3 (b) is the modified equivalent circuit with symmetrical brush positions, and Fig. 3 (c) is the theoretical circuit for unsymmetrical brush positions.

4.—Sources of Error in the Theory.

The theory is subject to all the errors which occur in the theory of ordinary induction motors and, as a matter of fact, in all alternating current machinery theory. In machines fluxes, currents and voltages do not vary harmonically as has been assumed. These errors will be more apparent for heavy overloads. The primary leakage reactance has been assumed constant. This is not so. As the brush-spread is increased more commutator winding conductors carry current, thus causing a variation in the value of the leakage reactance.

A very serious source of error is the assumption that the secondary resistance is constant. The secondary may conveni-

ently be divided into three parts: (i) the stator winding, (ii) the brush halves and (iii) a section of the commutator winding. The resistance of (i) is constant, that of (ii) is dependent upon speed to a certain extent, but is chiefly affected by the current. The resistance of the commutator winding (iii) varies with the brush-spread. In the machine that was used to verify the theory no appreciable variation in this resistance was detected. Since the radius and position of centre of the circle diagram are functions of r_2, to be correct, a separate diagram must be drawn for each value of the secondary current. A partial correction can be made by using an average value for the secondary resistance.



Figs 3 a), 3 (b), 3 (c),

There is also a variable brush resistance at the primary slip-rings; it is usually negligibly small.

For unsymmetrical brush positions an appreciable error will occur with large brush-axis displacements; the theory is only true for small values of δ.

5.—Conclusions.

For a complete mathematical analysis, and for a comprehensive series of test results, reference should be made to a thesis entitled "A Study of the Polyphase Variable Speed Commutator Motor," submitted to the University of South Africa for the degree of Master of Science in Engineering, in the department of Electrical Engineering, by the author.

This motor, then, which has the necessary characteristics of a truly variable speed motor, in that all speeds within the range can be obtained, and also that the speed is independent of the load, is admirably suited for any duty where the operating conditions demand these features. The speed of the motor passes, under control, through every revolution of its speed range, and thus uniform and gradual acceleration is obtained.

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TWO STATION DIRECTION FINDING WITH THE CATHODE RAY OSCILLOGRAPH IN SOUTH AFRICA

BY

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With 8 Text Figures.

Read 7 July, 1938.

At the 1935 meeting of this Association held at Paarl, a demonstration was given of a Cathode Ray Oscillograph Direction Finder for the determination of the direction of arrival of atmospherics, and a description of that apparatus appeared in a paper read before Section A at that meeting. The apparatus was subsequently erected at the University of Capetown, and a series of observations were made with it by Schonland and Hodges on the bearings of atmospherics from Capetown. These observations were taken over a period during September and October, 1935, on 26 different days. This work was essentially of a preliminary nature, its primary object being to investigate the possibility of applying the method to the determination of the sources of atmospherics in South Africa. It is well-known that atmospherics in the main originate in regions of disturbed weather, and the analysis of the results from this preliminary investigation clearly indicated the close relation existing between sources of atmospherics and the active storm centres during the period of the investigation, as reported by the Meteorological Departments of South Africa and Southern Rhodesia.

This early work clearly indicated the efficiency of the apparatus in locating bearings, and its value as an adjunct to the meteorological methods at present in use in South Africa. With a single station, however, such as that at Capetown, a single bearing on any source merely indicated the direction of the source, and the average amplitude of the signals received from the source had to be employed to estimate its distance from the station.

At the beginning of 1937 the Bernard Price Institute of Geophysical Research was established at the University of the

Witwatersrand, under the Directorship of Professor Schonland, and it was then decided to proceed with a full investigation of the method as applied to South African conditions. It was decided to establish two stations on a more or less permanent basis, the one at the Bernard Price Institute, under the control of Professor Schonland, and the other at the Natal University College, Durban, to be erected by Dr. D. B. Hodges. One of the two authors (L.K.), having obtained a grant from the Research Grant Board, proceeded to Johannesburg, and spent 1937 at the Bernard Price Insitute, first building and assembling the apparatus and equipment for the Direction Finder, and subsequently operating that station under the direction of Professor Schonland. The other (W.E.P.) has been operating the Durban station with Dr. Hodges during this period.

Equipment of the Two Stations.

It was felt desirable, in order to make the scope of the investigation as wide as possible, to increase the range of the instruments at each of the stations beyond that of the original station at Capetown. The stations might then be utilised, not only to locate sources within the Union, but well beyond its boundaries. It was particularly important that this should be done in view of the fact that it was intended to utilise the stations in the investigation of the wave form of atmospherics. By means of gain controls the range of the instruments could then be curtailed when near sources were under investigation. In addition, each station was equipped with a sense determination device. This, it was felt, would serve more than one purpose. In the case of very distant sources, where the difference in the bearings at the two stations might be too small to make accurate intersection possible, the sense device would indicate the correct quadrant for the location of such sources. Further, should bearings have been incorrectly identified as having occurred simultaneously at the two stations, the sense device might indicate this fact by placing the source in a different quadrant from that in which it was located by the two bearings. Finally, when single station observations were recorded, the sense device was essential for the location of any source in its correct quadrant.

The equipment at the Durban station follows in general that of the original station at Capetown, except that its range is increased, it is equipped with a sense device, and is operated from the A.C. mains in the place of batteries. The equipment at the Johannesburg station is of an improved type, using push-pull output.

Mode of Operation.

The two stations at Johannesburg and Durban were erected and equipped during the first portion of 1937, and they were in full working order before the beginning of September of that year. Subsequently, simultaneous observations were made

each day, except Sunday, at the two stations, over a period of approximately four months, from 2nd September to 24th December, 1937. The trunk telephone line used for intercommunication between the two stations was made available through the kindness of the Postmaster-General for 15 minutes from 1 p.m. each day, and this determined the period of the day at which the simultaneous observations were made.

In addition, single station observations for a period of 15 minutes were carried out twice daily at the Johannesburg station during this period, once in the forenoon, usually between 9 a.m. and 10 a.m., and once in the afternoon, usually between 3.30 p.m. and 4.30 p.m. Since the period of the day at which simultaneous observations could be made by the two stations could not conveniently be varied at will, these single station observations enabled sources, not in active operation during that period, to be observed and recorded, and, in addition, it was in this way possible to trace the movements of certain sources and "cold fronts."

Results of the Investigation.

It is not possible, at this stage, to do more than indicate a few of the results obtained in the investigation. It has already been pointed out that the method of direction finding here employed would have to be tested over a relatively long period of time before a comprehensive report on the method could be issued. In this connection it may be noted that the results obtained from the period of working of the two stations during 1937 were sufficiently valuable to justify a further period, and it has been decided to continue the work during the whole of 1938. Daily readings by the two stations were recommenced on 1st February of this year, and are proceeding satisfactorily at the present time.

Single Station Observations.

Following the lines of the preliminary investigation from the Capetown station in 1935, an analysis has been made of the single station readings from Johannesburg. These have been compared with the meteorological maps for the corresponding periods, with the result that the early conclusions have been mainly confirmed. In the case of thunderstorms reported and recorded on the meteorological maps, it was found that in 82 per cent. of these cases the bearings obtained by the Direction Finder corresponded within 5° with the reported localities, and 69 per cent corresponded within 3°. When it is remembered that the maps cover the whole 24 hours of each day, while the Direction Finder was only in operation over short periods of the morning and afternoon, the correlation of the observed bearings of atmospherics with the location of reported thunderstorms is strikingly high.

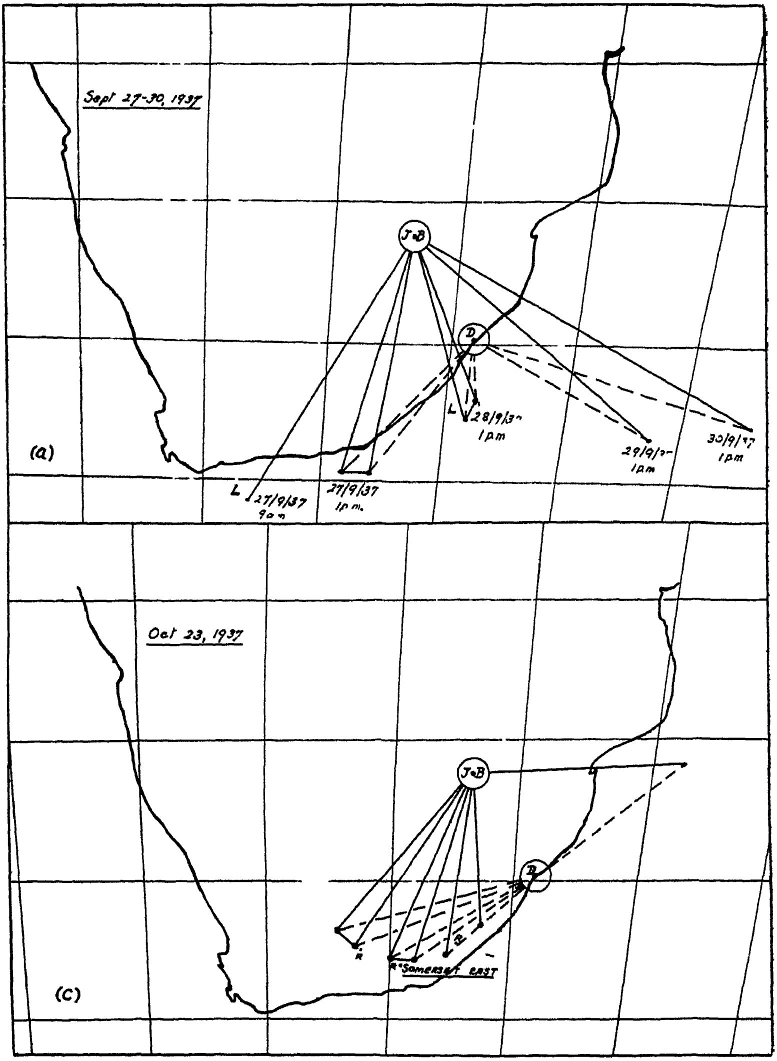
An attempt was also made to correlate observed bearings with the reports of coastal "lows" on the maps. Although in 15 our of the 22 cases examined in this connection, signals were received from the direction of these areas, it was realised that the position of the centre of a "low" area, as indicated by the meteorological map, need not coincide with a region of thunderstorm activity.

Simultaneous Observations at the Two Stations.

As has been previously mentioned, simultaneous observations at the two stations were obtained daily at 1 p.m. When it is remembered that the majority of thunderstorms over land areas in South Africa occur fairly late in the afternoon, and that no reports can be obtained of storms occurring over the sea, a statistical analysis of the results from the meteorological maps with those from the two-station working would furnish little information. It is considered preferable, at this stage, not to attempt such an analysis, but to report certain individual results. These are presented in the form of maps, on which are indicated the location of individual sources by the Direction Finders, together with the relevant information obtained from the meteorological maps for the corresponding period, and from other sources.

These maps illustrate several points of interest. In the first place they provide confirmation of the thunderstorm origin of the signals received at the two stations. Reference to the map for 2nd October indicates that a thunderstorm was actually in operation over Durban at the time the two stations were in inter-communication. The operator at the Durban station was thus able to signal actual flashes as they occurred, and it will be seen that the bearings of these as recorded by the Johannesburg station correspond with the bearing of the Durban station from Johannesburg. Similarly a thunderstorm over Johannesburg on 24th December enabled the Durban station operator to correlate bearings on Johannesburg with flashes reported from that station. Reports of thunderstorms actually in progress at 1 p.m on certain days have been received directly by the Johannesburg station from other sources than the meteorological reports, and they have indicated that the intersection of bearings obtained at the two stations located an active source at the point where the storm was in operation. Such direct correlations have been obtained at localities as far apart as Somerset East, Volksrust and Bulawayo.

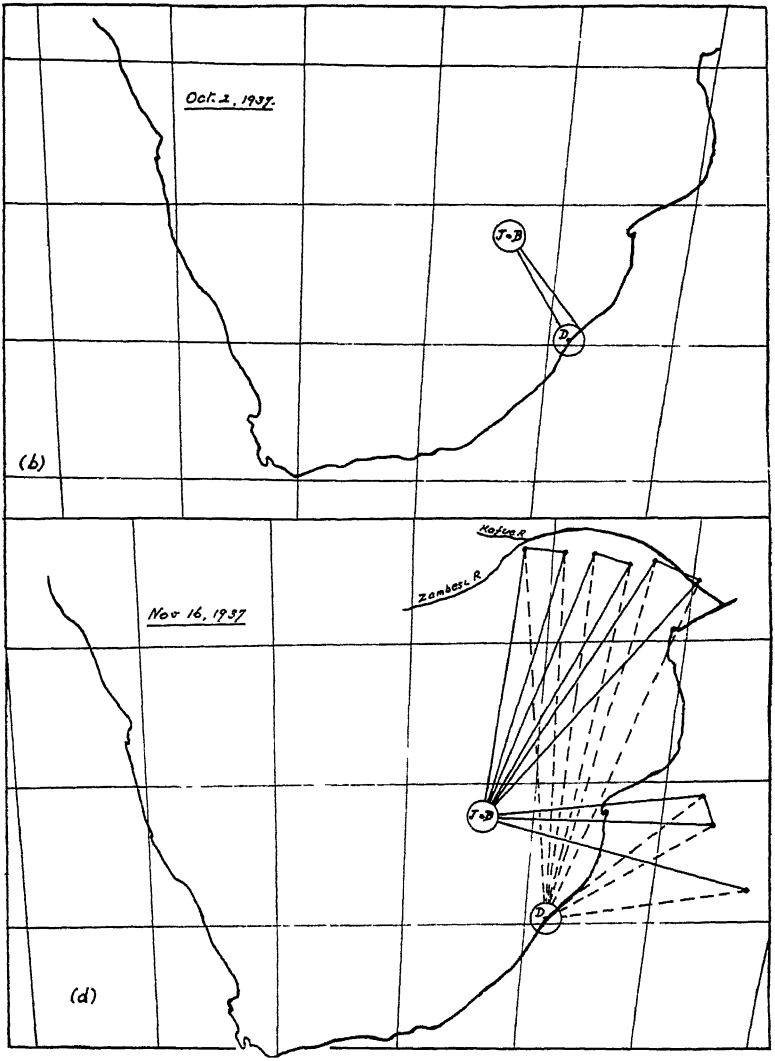
The method has also enabled areas of meteorological disturbance or "fronts" to be located, and their movements followed, sometimes for comparatively long periods. The maps provide examples of the location of such "fronts," not only within the Union, but over the sea off the coast, and their subsequent movements. An example, too, has been included to illustrate the value such a method might be to aviation.



J.B.—Johannesburg station. D.—Durban station. L.—Low reported by Meteorological Dept. R.—Rain reported by Meteorological Dept.

(a) The map shows the bearings obtained on successive days (27th to 30th Sept., 1937) and indicates how the movement of the depression could be followed from day to day. No "lows" were reported by the Union Meteorological Dept. on Sept. 29th or Sept. 30th.

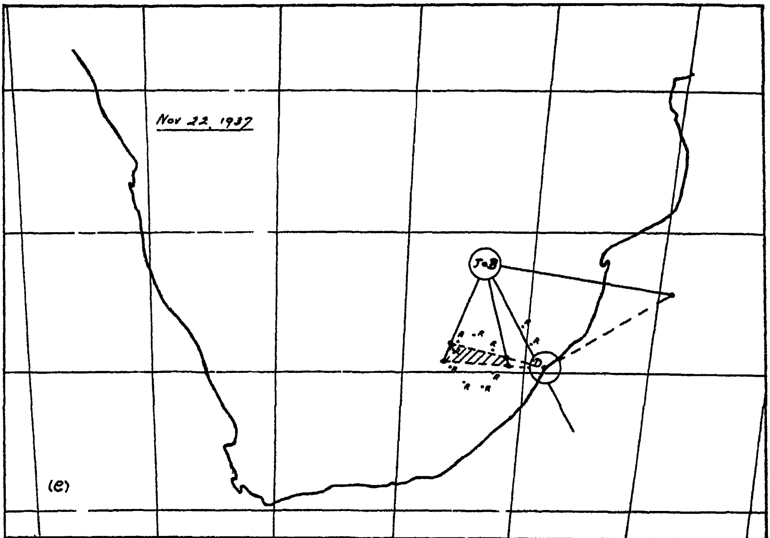
(c) This map indicates the accuracy of the locations The map further indicates that while it would have been impossible to fly direct from Johannesburg to Port Elizabeth, the route via Durban could have been used.

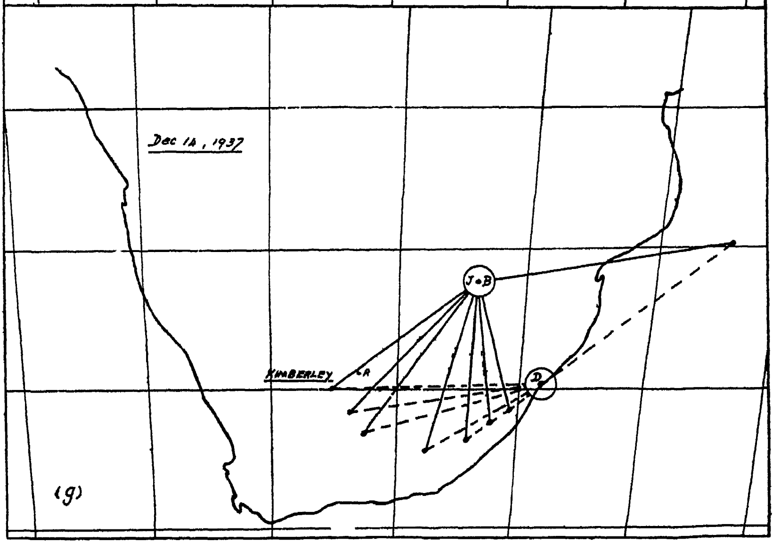


J.B.—Johannesburg station. D.—Durban station.

(b) No observations could be made at the Durban station as the thunderstorm was in and around Durban. The map shows how the bearings of atmospherics received in Johannesburg correspond with the bearings of the thunderstorm in Durban.

(d) The locations indicated an extensive " front " along the Zambesi Valley. Information later received from the Rhodesian Meteorological Dept. stated that data indicated a " cold front " had existed on Nov. 16th, 1937, which extended from the mouth of the Zambesi River to the junction of the Kafue River.

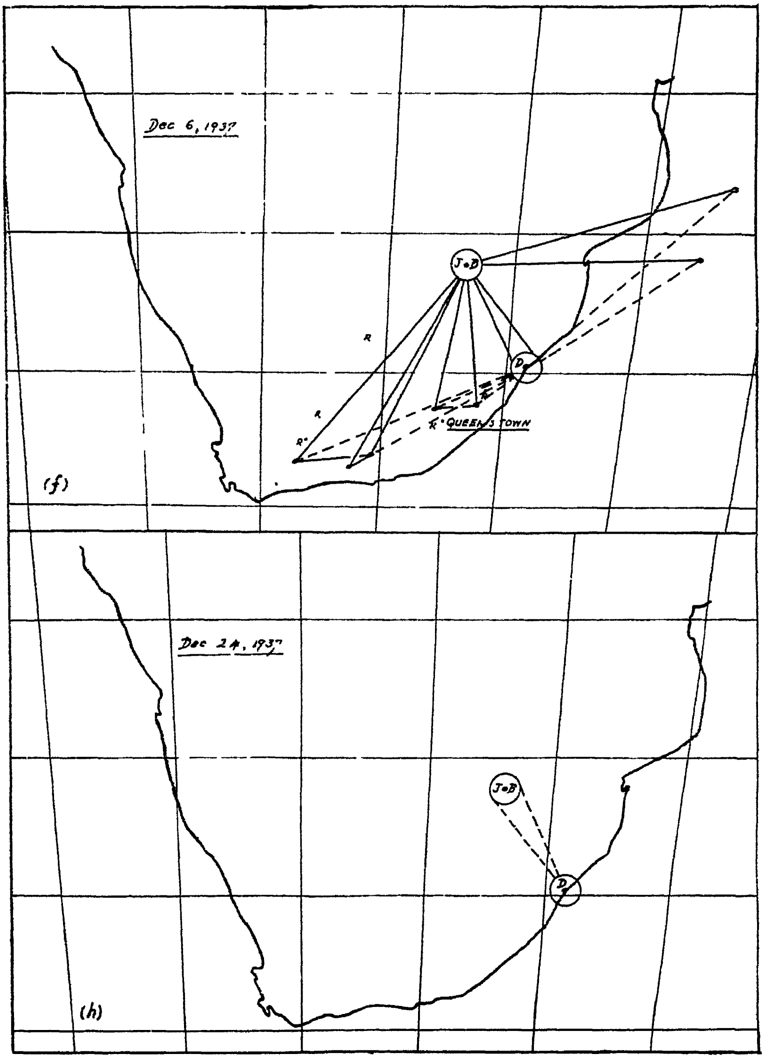




J.B.—Johannesburg station. D.—Durban station. R.—Rain reported by Meteorological Dept.

(e) At 2.30 p.m. a thunderstorm was overhead in Durban. Note the correspondence of the regions from which heavy rains were reported and the location of the source of the atmospherics.

(g) The locations indicate that there was one extensive " front " stretching across the Union. This corresponds with the fact that soaking rains were later reported from many parts of the country. At 3.30 p.m. a Currie Cup cricket match at Kimberley was interrupted by a violent thunderstorm.



J.B.—Johannesburg station. D.—Durban station. R.—Rain reported by Meteorological Dept.

(f) A thunderstorm was known to have taken place during the afternoon. A storm near Durban caused an interruption of the telephonic communication between the two stations and prevented the completion of the observations.

(h) Thunderstorm in Johannesburg. The bearings received in Durban correspond with the general direction of Johannesburg.

In conclusion the authors would like to indicate that the investigation is being carried out in part with the assistance of grants from the Research Grant Board of South Africa, and that a full report on the complete work in connection with the investigation will be published at a future date.

The authors wish to thank Professor B. F. J. Schonland, Professor D. B. Hodges, and Mr. J .W. van Wyk, B.Sc., whose valuable assistance made this paper possible.

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NOTE ON A MONOTONIC PROPERTY OF A PRODUCT OF HANKEL FUNCTIONS

BY

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Read 5 July, 1938.

THE EVALUATION OF CERTAIN INTEGRALS INVOLVING PRODUCTS OF CONFLUENT HYPERGEOMETRIC FUNCTIONS

BY

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Read 5 July, 1938.

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A COMPARISON OF SOME CHERTS AND FLINTS

BY

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With 4 Text Figures.

Read 5 July, 1938.

Recently there has been some demand for a low iron, high silica rock, with a rapid inversion of the low quartz on heating to high temperature. In Europe cherts and flints in a finely-ground state are used in the porcelain industry to counteract the high shrinkage and liability to crack of the very plastic ball and china clays.

The manufacture of porcelain ware is being carried on in a small way at Olifantsfontein. With the raw material available it is not possible to compete with "finer" imported porcelain (cups, saucers and other ornamental articles), but the manufacture of plain and ornamental tiles and sanitary ware is an economic possibility worthy of investigation.

A detailed comparison of cherts and flints used overseas and the material available in the vicinity of the Witwatersrand area seemed desirable.

Cherts and Flints.

According to Twenhofel (1932), chert includes "those crypto-crystalline varieties of quartz which are white, grey or other light colours. Flint includes the dark grey and black varieties of the same material."

No reference is made to textural or mineralogical differences between chert and flint. The examination, however, showed that flint pebbles from the chalk measures in Denmark and England differed somewhat from chert of about the same age. Specimens obtained from England, Denmark and the Dolomite Series of the Transvaal System were compared. Some data of chert occurring in Missouri and France is appended as well.

"Silica" for use in porcelain ware must comply with these two specifications:—

1. The iron, titanium and manganese oxide contents must be low.

2. The inversion of low quartz must be rapid. Chalcedony is a desirable constituent. Calcite, dolomite, limonite, etc., should occur in very small quantities.

The study will therefore be divided into two parts: —

A. Chemical Composition.

B. Petrographic Examination.

A. *Chemical Composition.*

The chemical compositions of cherts and flints from America, England, Denmark, France and South Africa are given in Table I. It will be noted that many of the samples from the Dolomite Series are higher in iron than the overseas material.

TABLE I.

	1.	2.	3.	4.	5.	6.
SiO_2	97·10	97·70	96·78	96·67	98·31	99·25
Al_2O_3	1·43	1·08	1·86	1·59	0·38	0·20
Fe_2O_3	0·51	0·09		0·48	0·17	0·09
TiO_2	Nil	Nil	—	—	—	—
MnO	Nil	Nil	—	—	—	—
CaO	0·02	0·11	0·26	0·07	0·46	—
MgO	0·02	0·10	0·07	—	0·20	—
Na_2O	—	—	—	0·16	—	—
K_2O	—	—	—	0·05	—	—
Loss on Ignition	0·42	0·95	1·00	1·26	0·67	0·35
	99·50	100·03	99·97	100·28	100·19	99·89
Specific Gravity	2·65	2·41	—	—	—	—

1. Chert near Witkop Station, Vereeniging Line (Bosazza, 1937b).
2. Waterground flint from chalk, England (Bosazza, 1937b).
3. Flint, Denmark (Stanley, 1908).
4. Chert, Indiana, U.S.A. (Ross, 1919).
5. Average of three analyses of flint from France (Weigel, 1927).
6. American flint (Weigel, 1927).

Manganese and titanium oxides are present in traces or absent. The gradual change of dolomite to chert gives rise to zones of calcareous chert, and this is the chief objection to the use of this material (Bosazza, 1937b). On the other hand, the untreated English material is quite high in lime. Refer to Table II. Carbonates of lime and magnesia are easily detected by loss on ignition determinations, so that the mining operations can be controlled and the elimination of contaminated material will be fairly easy.

The zones of chertification are well developed and fairly free from unaltered dolomite (Bosazza 1937b). Some higher grade material has been found and the analytical data is given in Table II, with two analyses from the chalk, Kent.

TABLE II.

	1.	2.	3.
SiO_2	96·20	74·10	98·00
Al_2O_3	0·40	2·32	2·34
Fe_2O_3	0·93	1·39	0·19
TiO_2	Nil	Nil	Nil
MnO	Nil	Nil	Nil
CaO	0·95	11·50	Trace
MgO	0·14	1·51	Nil
Loss on Ignition	1·64	9·21	0·10
	100·26	100·03	100·63
Specific Gravity	2·65	—	2·63

1. Flint from chalk, Kent (Analyst, V.L.B.).
2. Banded chert from Upper Greensand, Devonshire (Analyst, V.L.B.).
3. Chert, Vereeniging Road (Bosazza, 1937b).

B. *Petrographic Examination.*

Petrographic examination has shown marked differences between the specimens obtained from the various localities.

Chert and flint from Kent were examined and some marked textural differences observed. On the average the flint is very much finer grained, the crystal grain size being about 0·05 mms. and less, coarser grained portions also occurring. Rodlike and radiating structures are fairly common (Fig. 1). The radiating structures, consisting of low quartz particles, appear to be more common in the chert, which is fairly coarse-grained (Fig. 2). Low quartz particles of 1 mm. are common, the average being about 0·5 mms. Calcite and dolomite are common impurities in both the flint and chert from Kent. The rodlike structures are common in the flint from Denmark (Fig. 3). No calcite or dolomite have been observed. These lath-shaped structures are probably fossil remains. The " rosettes " of quartz are due to crystallisation about a nucleus.

In the South African material opal and chalcedony have not been observed. Calcite and dolomite are usually absent in the innermost zones of chertification. All the silica is in the form of low quartz and almost always exhibits an undulatory extinction. The average grain size is about 0·05 to 0·02 mms. diameter, although wide variations have been observed (Bosazza, 1937a and 1937b) (Fig. 4). Comparative figures are given in Table III.

The rate of decrepitation of the chert is high, so that calcination would readily effect disintegration of the material, thus reducing the liability of metallic iron being introduced by abrasion during crushing.

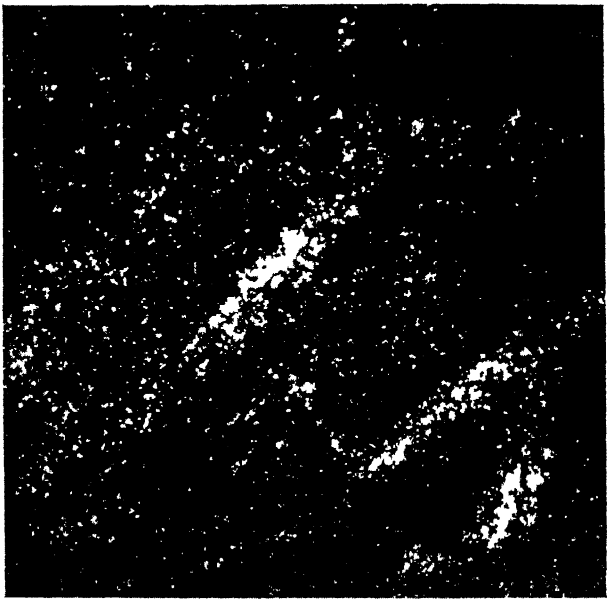

Fig 1

Flint Kent Crossed Nicols (× 100)

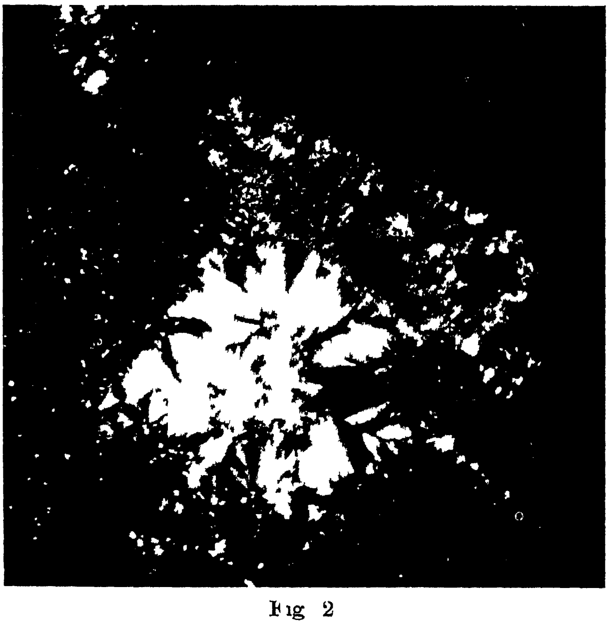

Fig 2

Chert Upper Greensand Crossed Nicols (× 100)

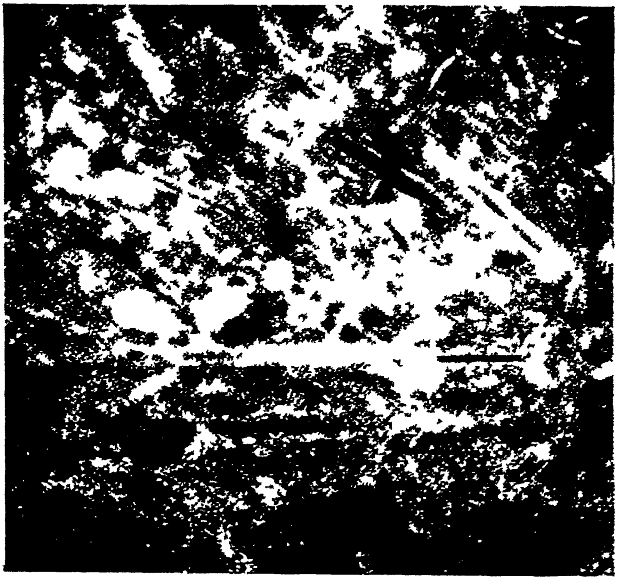

Fig 3
Flint Pebble Denmark Crossed Nicols × 100)

Fig 4
Chert Dolomite Series Six Mile Spruit, Pretoria
Crossed Nicols (× 60)

TABLE III—Rate of Inversion.

Rock.	Average Grain Size, mms.	Specific Gravity, Raw.	Specific Gravity After Heating to 1470°—1500°C. for Two Hours.
Chert	0·02	2·65	2·18
Quartzite	0·20	2·65	2·43

Although some textural and mineralogical differences have been noted in the various cherts and flints (Stanley, 1908), no features disfavouring the use of South African material have been observed.

CONCLUSIONS.

Preliminary tests on the manufacture of porcelain, using chert from the Dolomite Series and china clay from various localities, have shown that compared with English china clay and water ground flint from Kent the higher iron oxide content affects the colour to a slight extent. The slight buff colour of the experimental porcelain was not a serious disadvantage in the type of ware indicated in the introduction. The establishment of a large scale porcelain industry is hampered by the lack of high grade china clays and potash feldspars. The manufacture of "structural" ware, i.e. tiles and sanitary ware, is definitely possible with the china clays and chert available. The possibilities of making high and low tension electrical insulators are not beset with many difficulties from the ceramic point of view.

Economic factors, however, must be considered.

ACKNOWLEDGMENTS.

I am indebted to Professor G. H. Stanley, Director of the Minerals Research Laboratory, for the loan of specimens and photomicrographs.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 199-203, December, 1938.*

NOTE ON A MUDFLOW AT NDWEDWE, NATAL*

BY

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With 5 Text Figures.

Read 5 July, 1938.

The mudflow is reported to have taken place about 4 p.m. on February 8th, 1938, in a small valley about three miles west of Ndwedwe Magistracy, and to have been accompanied by an explosion which was heard over a wide area. The writers were not able, however, to examine it until the 26th of March, when it was found to be in a very fresh state of preservation and little affected by the intervening rains.

The material of the flow was a black carbonaceous mud or bog soil, very tenacious and riddled with rootlets and vegetable debris. Included in it were many undigested fragments of quartz, granite, pegmatite and schist. The whole was saturated with water except where surface slabs had dried out by the heat of the sun after the disturbance took place.

While an explosion, probably of pent up marsh gases, undoubtedly started the phenomenon into motion, gravity alone was responsible for almost all the movements involved. Though no primary data upon the magnitude of the explosion are available, the observations recorded below clearly indicate that it exercised little more than a trigger action, setting a heavy, waterlogged mass of soil into violent motion. Nevertheless, the occurrence of any explosion at all is important, and in the writers' view it may be attributed to a sealing off of the vents by which hydrocarbons from the decomposing vegetation usually reached the air. The substance of the mudflow suggests that solidified hydocarbons themselves, in conjunction with silt brought in by early rains, may have operated to prevent escape of gases as they were generated, or until such time as a bursting pressure was reached and spontaneous combustion exploded the mass.

The course of the flow may be studied in three parts: (a) an upper, marshy section where the upheaval originated, (b) an intermediate tract down a small side-valley along which it travelled, and (c) an area of accumulation in a somewhat larger valley wherein the bulk of the material came to rest.

* Natal University College Geomorphic Studies, No. 3.

Fig 1—The head of the disturbance, showing slumped blocks and the flow-scar in the foreground, with intact marsh behind

[Photo L C King

Fig 2—Torn and ruptured marsh in foreground with slumped walls on either side View downstream

[Photo L C King

(a) The area over which disruption is indicated by cracking and slipping of segments of the marsh is about 220 feet long and 50 feet wide, including the fissured ground adjoining that actually torn away The scar whence material was removed lies within this and measures 36—40 feet across

Near the head, blocks of soil with the vegetation still flourishing upon them are turned back as though they had slipped along curved shears and the sides of this section have also slipped towards the central cavity after the manner of step-faulting, movement of two or three feet occurring along some of the fissures. The rest of the area exhibits only a jumble of blocks without any definite arrangement. Some of these blocks may conceivably have been pitched forward by the force of the explosion, but clear evidence in support of the contention is difficult to obtain and in no case was it found necessary to assume violent explosion to account for their present attitudes or positions. The first slickensides along the walls of the trough occur 100 feet from the head of the hollow.

In the whole of this section, there is no evidence of material being thrown *out* of the hollow by explosive action and all the structures preserved within it are in accord with sliding under gravity alone.

Fig. 3.—Slickensided trough-walls near the head of the middle section of the flow. Transverse cracking has been induced by subsequent drying out of the wall-material. Note the block thrown out and tilted away from the channel.

[*Photo. R. M. Jehu.*

(b) The middle tract is essentially a zone of travel commencing about 70 yards from the head and maintaining a width of 40 feet for another 120 yards. The floor is relatively smooth and represents the pre-flow valley floor on which the original grass is still growing. For so little disruption of the floor to take place, the lower portions of the travelling flow must have been in a very fluid condition. Pieces of mud occur at a height of 8-10 feet in the branches of trees which were enveloped as the mud slid past and, though it is not impossible that these

were thrown there, it appeared to the writers that some, at least, were part of the main body of the flow, which therefore must have been of comparable depth.

Fig. 4.—The "zone of travel," channel entering on the left, and bordered by "leveés" or earthworks.

[Photo. L. C. King.

The sides of the main line of flow are here bordered by two continuous walls or "leveés" of sods thrown out by the passing slide. The two lines are remarkably straight and even-crested, and are composed predominantly of masses of earth knitted together by vegetation. These have been overturned as they grounded on the valley-sides, their present attitudes being comparable with clods cut and turned by a plough.

The top of these earthworks probably indicates the maximum height of flow (8 feet), an estimate which is in accord with the level of the mud held in the forks of trees.

Slickensides are abundant on the faces of blocks in this tract of the mudflow course, the general appearance of many surfaces being similar to that of a till which has been overridden by renewed ice-advance. This is especially well shown near the head of this (middle) section where the channel was narrowed by the failure of one bank to tear away completely, though it was fissured and wrenched out of position.

A few large aloes and bamboos were overthrown by the flowing mass and are now embedded in the mud of the side walls.

At the lower end of the middle section, the declivity steepens towards a junction with a larger valley. Here the floor is even cleaner of debris and shows the pre-flow valley-floor almost without modification and with a thick mat of grass still present. The only change resulting from the passage of the flow is where a

piece 15 feet long and 3 feet deep was torn away from a bed and carried forward with the main slide. At this point the earthworks die away and, with the reaching of the larger valley, a depositional phase sets in.

Fig. 5.—The "zone of accumulation," showing the general mud deposit a few inches thick and the numerous sods floated down by the flow.

[*Photo. R. M. Jehu.*

(c) The lower part is an area of accumulation. From the small tributary valley the flow swung to the right in a wide arc down a larger valley and gradually came to rest. Here the lateral walls are absent; but the tongue of debris, being higher on the left-hand side, deflected the stream in the larger valley, displacing it along the margin of the flow and two or three feet above its former level.

The surface of the deposited mud is broadly convex, though very rough, the thickness towards the terminus being only a few inches. The area occupied by the depositional phase is some 60 yards long by 25 yards wide and ends quite sharply, though rolled fragments occur some distance beyond the actual terminal edge.

Conclusion.

A mudflow at Ndwedwe, Natal, was motivated by an explosion of marsh gas which set in motion part of a small bog resting in a hollow near the head of a small valley. The phenomenon exhibits most of the features usually associated with mudflows in a high degree of perfection.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 204-208, December, 1938.*

THE STERKFONTEIN BONE BRECCIA: A GEOLOGICAL NOTE

BY

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With 1 Plate and 1 Text Figure.

Read 7 July, 1938.

On the farm Sterkfontein No. 68, about six miles from Krugersdorp, a number of caves occur in the dolomitic limestone belonging to the Dolomite Series of the Transvaal System. These caverns owe their origin to solution of the dolomite † by meteoric waters passing through fissures or joints. Some of the caves are rich in stalactites and stalagmites and are open to the inspection of visitors. A brief examination of the stalactitic caves showed that they form two lines of galleries developed along two main fissure directions running approximately north from their entrances and following more or less the general dip of the dolomite. The main galleries are connected at intervals by irregular caverns or passages developed along secondary joint planes at right angles to the main directions.

The "bone breccia" is exposed in an open working on the top of a rise, on either side of which are the entrances to the two main galleries of caverns already referred to. It is apparent that the deposit was laid down in a cave which formerly connected the two main galleries, but that erosion and quarrying have now exposed it. During a recent visit to inspect the type locality of *Australopithecus transvaalensis*, Broom (1), it was noticed that the breccia exhibited features which were not consistent with its being a normal cavern lair deposit. The opportunity was therefore taken to make a plan of the deposit and to undertake a more detailed examination before the already extensive destruction of the available evidence could proceed much further.

The plan of the workings is shown in the accompanying figure (Figure 1), and indicates the site of the former cave, the upper part of which has been destroyed by quarrying operations.

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* This paper read before before Section E has been included in Section B in error.—Ed.

† The term "dolomite" in this communication is used in its popular sense instead of the more correct but clumsy "dolomitic limestone."

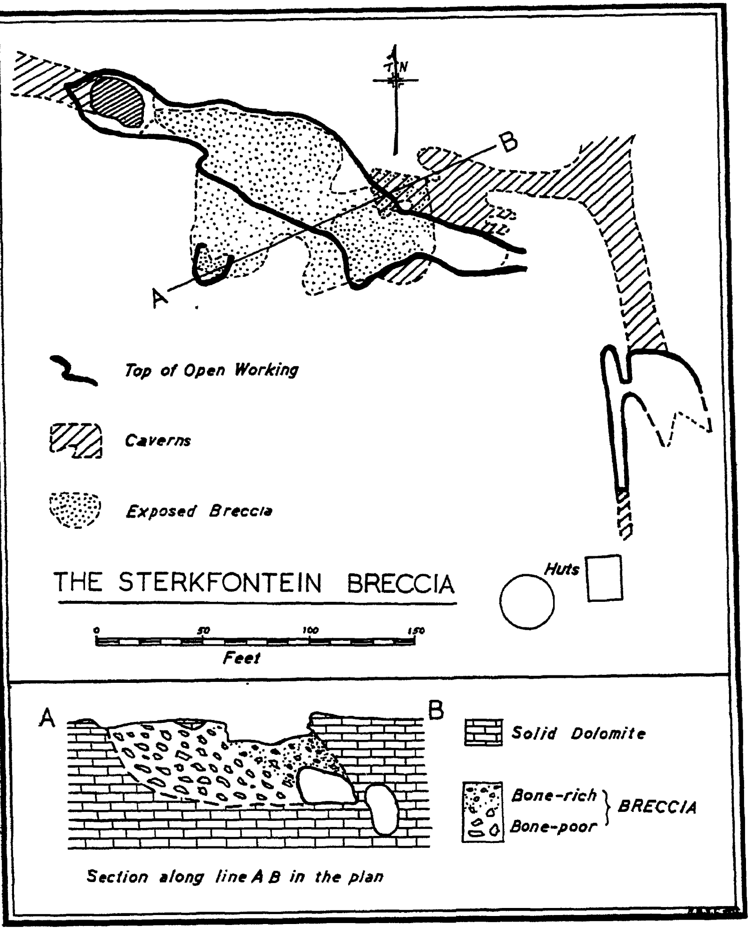

Fig. 1.

Plan and section of the breccia at the main quarry, showing the quarry boundary and underground caves.

The quarry is about six to ten feet deep, and the northern wall is solid dolomite almost to its foot. This wall and a portion to the south are all that remain of the original roof of the cave in which the breccia was laid down. The southern wall of the quarry is formed largely of the material of the breccia itself, but the contact of the breccia with the original cave wall is visible at various points in the quarry and is also to be seen in a small pit to the south. At the eastern end of the upper quarry the breccia forms a fairly steep slope running down into a lower cave (Plate I, Fig. 1), and is further exposed there as the result of quarrying. The finer bone-bearing portion of the

breccia is exposed in contact with the former cave roof at the foot of the north wall of the quarry.

The greater part of the breccia as exposed consists of a variety of dolomite boulders and fragments, ranging from a few inches to two feet in length, embedded in a matrix of well cemented reddish sand. Streaks of white calcite run through the matrix in all directions but trend mainly along the dip direction. The boulders themselves are of varying character, some, particularly the largest, being angular and fresh, others being rounded to a widely differing degree and showing weathered alteration to varying depths (Plate I, Fig. 2). In the main, the boulders and pebbles show the same characters as are exhibited by those at present found on the surface all over the dolomite country, and there is little doubt that they were formed on the surface prior to their transportation to their present position. The fresh angular blocks are thought to be derived from the collapse of a thin part of the original cave roof.

The major part of the breccia is sparsely or not at all bone-bearing, but the uppermost portion (see section, Figure 1) contains fairly abundant bone fragments, almost invariably broken, bearing to the matrix the same relation as do the boulders and pebbles. There is, however, a marked tendency for the size of the boulders and pebbles to decrease as the bone fragments increase in quantity, and a concurrent trend for the proportion of matrix relative to included material to increase. It must be stressed, however, that there is no evidence of any sharp change from bone-free to bone-bearing breccia, but every indication of a gradual transition. It is also notable that the richer bone-bearing material occupies a zone which is not horizontal but slopes at an angle suggestive of a talus or slumping origin. This conclusion is further borne out by the fact that the lower cave was only partially filled with breccia and suggests that the material was introduced from the south-west.

It would appear, then, that the characters exhibited by the breccia are not those of a cave breccia deposited as the result of occupation, and this is supported by the absence of coprolites. It is also important to note that bones were found actually in contact with the original cave roof, and the matrix material was found partially or competely filling small cavities in the roof itself. The original cave roof, where it remains, is still extremely solid and has undoubtedly not collapsed as a whole on to the breccia.

The general conclusion arrived at, then, is that the breccia is an introduced deposit, but it is impossible to determine its original place of deposition prior to transportation. It is possible that the bone may have been derived from a former rock shelter or cave on a somewhat higher level though the actual succession suggests rather a normal process of slumping followed by the increasingly rapid introduction of the bone-bearing material from some locality not very far removed. Very similar bone-bearing

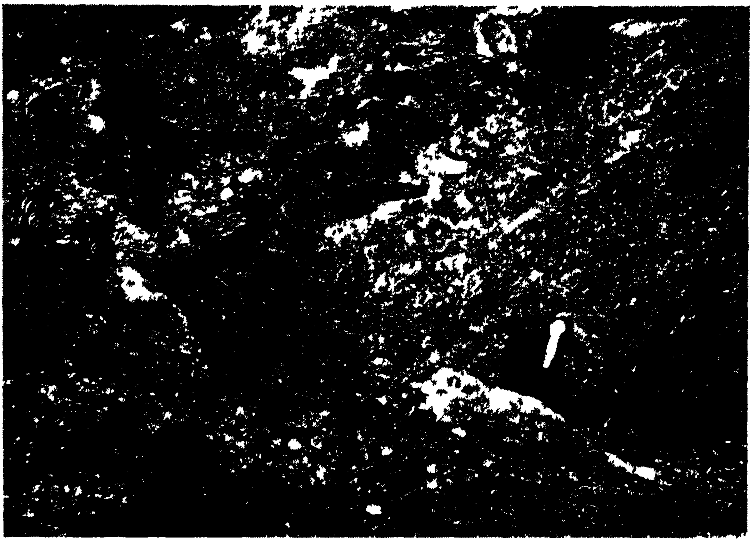

Fig. 1.

Slope of exposed breccia running from the upper quarry down into a lower cave.

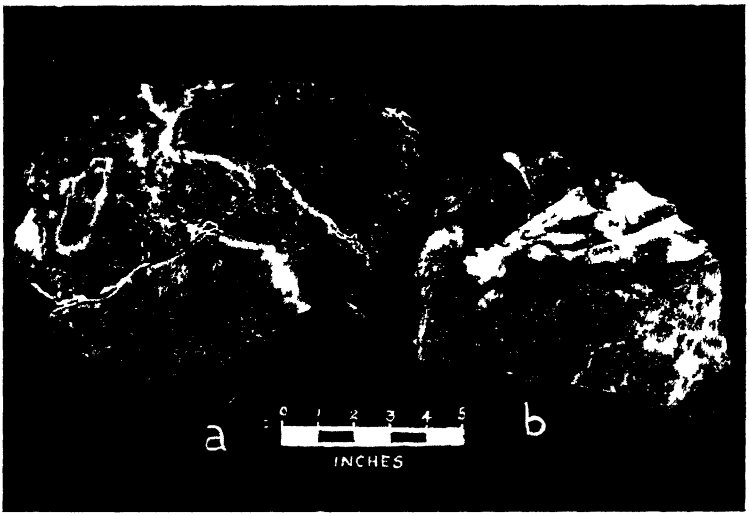

Fig 2.

Two pieces of the typical breccia: (a) bone-free type, showing form and weathered alteration of boulders and pebbles; (b) bone-rich type from the roof contact.

To face Page 206

breccias are found at several localities nearby, but these have not yet been examined in detail. One occurrence, in a collapsed cave about a mile east of the main deposit, appears almost identical with the uppermost zone previously described, but is less well cemented and lacks the coarse basal conglomeratic breccia.

A microscopic examination of the matrix of the breccia at the quarry shows that it consists almost entirely of calcite with a small proportion of quartz and chert grains and an unusual amount of limonite. The general character, allowing for the secondary cementation and replacement by calcite, is that of a rather coarse surface soil. Soil samples collected from various parts of Sterkfontein showed generally similar characters. The present-day soil, however, contains only a very small proportion of dolomite fragments and is rich in quartz and chert. The matrix material is so poor in chert and quartz that it must necessarily have been rich in dolomite originally, the dolomite being now mostly replaced by calcite. It seems probable, therefore, that the soil which now comprises the matrix of the breccia was formed under conditions permitting the existence on the surface of such relatively easily soluble material as comminuted dolomite fragments. This would point to a climate much more arid than that of the present day. It is also noteworthy that quartz and chert increase in quantity as the top of the deposit is approached, indicating a climatic trend towards a wetter phase during the later stages of deposition.

The onset of a more humid phase is clearly indicated in the thorough cementation of the breccia by calcite deposited from percolating solutions, and replacement by calcite of the original dolomite grains of the matrix. Calcite veins were also formed, particularly along the edges of the more angular boulders, and a stalagmitic layer, sometimes with intercalated thin streaks of manganous mud, was deposited on top of the matrix material partially filling cavities in the roof.

Further indications of climatic change prior to the deposition of the breccia are also present. In several places where the contact of the breccia with the former wall or roof is to be found, a deposit of secondary limestone occurs between the solid dolomite and the breccia. Blocks and fragments of secondary limestone were also found embedded in the breccia, and in one instance matrix material was found in a cavity in a secondary limestone which had partially filled an original cavity in the dolomite roof.

It would seem, then, that at least one wet phase had already preceded the dry one during which the matrix soil was formed, so that a cycle of *wet-dry-wet* is indicated, with the deposition occurring at the beginning of the more recent wet phase. The intense degree of the calcite impregnation of the matrix and the considerable erosion after cementation make it seem unlikely that it has taken place in the mildly wet phase

in which we are living. It is notable that Dr. P. A. Wagner (2) showed the existence of an earlier wet phase in the Limpopo basin, and that a series of alternating wet and dry phases has been more recently established in the Vaal River basin (3), the wet one preceding the present one being there distinguished as the " Third Wet Phase " and is probably Upper Pleistocene. It is possible that the more recent humid period at Sterkfontein is to be correlated with this phase and may even provide a connecting link between the two basins. The available evidence is, however, very slender and must be accepted with the utmost caution. If further palæontological evidence supports this suggested correlation, the sum of the evidence may provide a reasonable basis for assigning the deposit to a definite geological horizon, bearing in mind its secondary origin, whereas the palæontological evidence alone would not justify such action until correlation of African faunas with those of other regions has been effected and the factor of habitat disposed of

Two papers were presented to this Society in 1936 by Dr. R. Broom (1) and Mr. Trevor R. Jones (4) describing some of the vertebrate remains collected at Sterkfontein, and a further paper by Professor J. C. Middleton Shaw has recently appeared elsewhere (5), but in these accounts the geology of the deposit has necessarily been of subordinate interest. In view of the interesting nature of the climatic indications, the writer has presumed to present this account before the section dealing with Archæology, but it is hoped that it may also provide the geological background for the palæontological descriptions.

Acknowledgments.

The writer would like to acknowledge his gratitude to Mr. G. W. Barlow, Manager of the Sterkfontein Lime Works, for his kindness in permitting the examination to be made; to Mr. R. Greenberg for his assistance in mapping, and to Prof. C. van Riet Lowe for his helpful advice and kindness in communicating this paper during the writer's absence.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 209-212, December, 1938.*

SOME EFFECTS OF SILT POLLUTION OF THE NATAL COASTAL LAGOONS

BY

C. H. KARLSON.

Read 7 July, 1938.

The Natal Coast is a well-watered region. Numerous streams enter the sea through estuaries or lagoons of varying sizes. Though differing in detail all have a general similarity. The north bank is usually a narrow sandspit with the sea on one side and the lagoon on the other. On the south side there is often a bluff at whose foot the lagoon meets the sea. Durban Bay and its surroundings is a typical Natal lagoon on a large scale.

These lagoons vary from huge expanses of water like Durban, St. Lucia and Richards Bays to small affairs only a few yards in length. Some are almost entirely marine such as Durban Bay, which for its size and volume, receives comparatively little fresh water. The smaller lagoons are often closed by a sandbar for the greater part of the year and their waters are only slightly brackish. Most lagoons are more or less tidal and it is these that are of particular interest in this paper.

A typical unspoilt lagoon usually consists of a number of deep pools connected by channels of varying depth. These pools may be as much as ten or twelve feet deep. The bottom is usually sandy. At low tide sandbanks are frequently exposed. The colour of the water may be dark brown, grey-green or crystal clear, depending apparently upon the geological formation through which the tributary stream flows. Except in time of spate the waters are not silt-laden.

The lagoons are at their best during the winter and spring months. This is the period of spawning and the lagoons teem with larval fish, crustacean and molluscan life. The natural sequence of such an abundance of food is the presence of larger fish. Most of the migratory fish visiting the Natal Coast arrive at about this period.

The summer rains entail periods of spate and muddy water. There is a decrease in all types of estuarine fauna. Most fish move out to sea impelled, probably, both by a shortage of food and a dislike of muddy water. Late summer and early autumn finds estuarine conditions at their worst.

Purely estuarine fish are few in number, some species of mud and river breams and a few gabies and blennies. But there are numerous species equally at home in the lagoon or along the

littoral. Some apparently only use the sea as a means of travelling from one lagoon to another. While most fish enter to feed, many spawn as well.

The grey mullet is probably the commonest species. It is found in most lagoons throughout the year. At certain seasons, however, large runs from the sea occur. During the months of August and September, and invariably at night, I have seen the entrances of even small lagoons choked with mullet struggling to enter.

The various types of grunter form another common species and are found throughout the year yet arriving in shoals at certain periods. Other species found in lagoons in large numbers are the salmon bass, snapper salmon, silver bream and the rock salmon. However, under suitable conditions, almost all littoral-frequenting species enter; even soles have been captured.

Following these fish come the larger game species. In the bigger lagoons the largest specimens may enter though usually patrolling the nearby surf. These fish include the shad which arrives in large shoals during the months of September, October and November. The garrick is a winter visitor. The kingfish and barracouda are early summer arrivals. The various species of sharks are common during the greater part of the year, but most numerous during the spring and summer months. Some marine sharks do not seem to mind muddy water and large numbers may often be observed when rivers are in spate and conditions so bad that most other fish have fled.

Except in the case of herbaceous feeders like the mullet, the food-chain leading up to these game fish, seems to begin with such crustacea as the shrimp and the prawn. Not only is this borne out by examination of fish, but by anglers of experience, who find these crustacea the best of all baits. When these are absent or few in number there is a corresponding decrease in the number of fish in that particular lagoon.

Lagoons and their fauna such as have been described were once typical of the Natal Coast. To-day, with one or two exceptions, they may be encountered only south of the Umzimkulu and north of the Tugela.

A change in the character of some lagoons was first observed about thirty years ago. The process was slow up till about 1920. Since that time the deterioration has accelerated to such an extent that to-day there is hardly an unspoilt lagoon along the Natal Coast. Despite laws and regulations, fish have diminished in numbers, both in the lagoons and the adjacent surf until it is a serious problem in an area that regards itself as a national playground and where angling should be one of its greatest attractions.

The most obvious change in recent years is silting. In place of deep pools there is a narrow shallow channel. The bottom is no longer sandy but thick mud. The sandbanks formerly only exposed at low tide are now only covered by a few inches of water

at high tide. But worst of all the lagoon waters are almost perpetually muddy and silt-laden. Slowly, but surely, the period of dirty water, formerly confined to the rainy season, has increased to include the greater part of the year, and with it all the conditions peculiar to that period. Some lagoons, like those of the Illovo, Umhloti and Tongaat rivers have hardly any clear period. Silt pollution is now the normal, instead of the exceptional, condition.

The most important and far-reaching effect of this silt-pollution is the destruction of crustacean life. The cracker-shrimp, formerly inhabiting sandbanks in millions, cannot tolerate the soft ooze. Other shrimps and prawns retire up creeks and inlets where the water has some chance of settling. In a few lagoons it is difficult to capture a single specimen, in others the numbers are too small to form the basis of a food supply for fish. This seems to apply to all types of crustacean life from large crabs down to the micro-forms. Apparently they cannot tolerate prolonged muddy conditions. With the crustacea have gone the fish. South of the Umzimkulu and along the Pondoland Coast crustacea, fish and birds abound in every lagoon, the Natal Coast with one or two exceptions, is almost lifeless. They reappear north of the Tugela. In all cases their presence may be correllated with the amount of silt-pollution of the lagoons.

Though the mullet tolerates muddy water, I gain the impression that these have diminished in numbers, though this may be due to constriction of areas of lagoons following silting. It is rare to see the large mullet so common in St. Lucia Bay or along the Pondoland Coast. During periods of spate when the waters are even dirtier than usual, dead larval mullet may often be observed in large numbers. Possibly freedom from perseuction under present conditions is more than offset by a heavier larval mortality.

In the course of studying the Natal lagoons I have made a number of turbidity tests of the various lagoons. The examinations were made in a turbidimeter against a solution of kieselguhr according to the official method of the American Society of Agricultural Chemists. The water for examination was taken about halfway between the mouth and the tidal limit at full tide, during the months of August and September when the lagoons are at their best.

St. Lucia Bay...	1—100,000	Umdhloti ...	1— 4,000
Richards Bay ...	1— 90,000	Umgeni	1— 20,000
Tugela	1— 70,000	Illovo	1— 5,000
Sinkwazi	1— 90,000	Umkomaas ...	1— 70,000
Nonoti	1— 6,000	Ifafa	1— 50,000
Umvoti	1— 9,000	Umzumbi ...	1— 60,000
Umhlali	1— 5,000	Umzimkulu ...	1— 90,000
Tongaat	1— 4,000	Imbizana ...	1— 70,000
Umtamvuna ...	1— 90,000		

This table shows very well how turbid and silt-laden are the waters of the lagoons in the central area of Natal. The Tongaat and the Umdhloti are about 25 times as muddy as St. Lucia. My observations indicate that marine fish dislike readings below 1—30,000 and that crustacea tend to disappear from lagoons with readings below 1—20,000. However, in times of spate all lagoons will go to a very low figure, sometimes becoming quite opaque.

What is the reason for the conditions at present existing along the Natal Coast? Up till comparatively recently the Natal Coast was a well wooded region. For a while sugar cultivation seemed harmless. But since 1920 the area and production has increased enormously until to-day, over large districts, there is hardly an acre not cultivated. Silt-pollution coincides exactly with the area under cane and is worst where the cultivation is most intense.

It has long been observed that there is some connection between the sugar industry and the paucity of fish. Chemical pollution from the mills has been blamed. I do not think this was ever a serious factor. On several occasions I have observed that the first fish to show signs of distress following a flagrant breach of the pollution regulations are the mullet. Mullet are just as common to-day whether the lagoon has a mill on its tributary stream or not. Nor does the presence or absence of a mill seem to affect crustacea. Silt-pollution will be worst along such streams since in the vicinity of a sugar mill cane cultivation will be heaviest.

The correction of the present situation will depend on the larger one of prevention of soil-erosion. This may not restore the lagoons to their former conditions, but it will help to keep the water clean which will mean that some, at least, of the marine species will come inshore after the mullet.

The restoration of the lagoons may prove an impossible task since the wellbeing of a large industry is of more importance than the sport of angling, but it is important to realise the reason for the present conditions.

THE SILCRETES AND CLAYS OF THE RIVERSDALE-MOSSEL BAY AREA

BY

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Read 7 July, 1938

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 213-230, December, 1938.*

EXOTIC PASTURES IN THE GEORGE-KNYSNA AREA:

A STUDY OF FERTILITY, MILK PRODUCTION AND MANAGEMENT PROBLEMS ON KIKUYU AND OTHER INTRODUCED GRASSES

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and

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to

African Explosives and Industries, Ltd., Johannesburg.

With 2 Illustrations and 1 Text Figure.

Read 4 July, 1938.

The experiment herein described consisted of eight one-morgen camps on the farm of Mr. F. W. E. Leggett, "Tura-Kina," George, which lies on the seaward side of the Outeniqua mountains at an elevation of 600 feet. The soil is rather poor, as will be seen from the results of an analysis, kindly supplied by Mr. O. A. Langenegger, Extension Officer for this area. These samples were taken from an adjoining five-acre field which was put down to a pasture mixture in April, 1936.

Analysis of Soil Sample from "Tura-Kina," George.

	Topsoil.	Subsoil.
Total P_2O_5	·036%	·024%
Available P_2O_5	·003%	·0025%
Total K_2O	·330	·210
Available K_2O	·0042	·0035
Nitrogen	·103	·063
Organic Material	3·620	2·900
pH	5·700	6·180

After ploughing and working down the soil the eight camps were sown or planted in May and June, 1931. The first two camps were planted to the following mixtures:—

TABLE I—Sown Pasture Mixtures in lbs. per morgen.

Species.	Camp 1.	Camp 2.
Paspalum dilatatum	16	—
New Zealand Cocksfoot, *Dactylis glomerata* ...	8	—
Yorkshire fog, *Holcus lanatus*	6	32
Perennial rye, *Lolium perenne*	6	22
Italian rye, *Lolium italicum*	4	22
Westernwolth's rye, *Lolium westerwoldicum* ...	4	—
New Zealand wild white clover, *Trifolium repens* ...	4	8
New Zealand Tall Fescue, *Festuca elatior, sub, sp. arundinacea*	8	—
Phalaris tuberosa	2	—
Rescue grass, *Bromus unioloides*	4	16
Bromus inermis	6	—
Timothy, *Phleum pratense*	2	—
Tall Oat grass, *Arrhenatherum elatius*	4	—
Sheeps Burnet, *Poterium sanguisorba*	2	—
Herds grass, *Agrostis vulgaris*	2	—
Teff, *Eragrostis tef*	2	—
Kentucky Blue grass, *Poa pratensis*	2	—
Rhodes grass, *Chloris gayana*	2	—
Yellow trefoil, *Medicago lupulina*	2	—
Chewings Fescue, *Festuca duriuscula*	2	—
Sheeps Fescue, *Festuca ovina*	2	—
Wallaby grass, *Danthonia pilosa*	4	—
Subterranean clover, *Trifolium subterraneum* ...	4	—
Crested dogstail, *Cynosurus cristata* .. .	2	—
Total lbs. per morgen	100	100

Camps 3 to 8 were sown to a mixture of 4lbs. wild white clover and 12lbs. of Kentucky Blue Grass, *Poa pratensis*, per morgen and then planted with roots of kikuyu grass, *Pennisetum clandestinum*.

With regard to fertiliser treatments camps 1 and 2 were fertilised in strips, the areas of the strips being:—

PNK	... ...	⅛ of the camp.
PN	.. ...	¼ of the camp.
P	...	⅜ of the camp.
O	.. ..	⅛ of the camp.

The amounts of fertiliser applied were the same as those for the remaining camps, which received the following treatments:—

3	...	PNCa.	6	..	PN.
4	...	PNKCa.	7	...	P
5	...	PNK.	8	...	O.

Illustrations I and II—These views show the nature of the country, the forests, the proximity of the Outeniqua Mountains and the aspect towards the coast. These pictures were taken on two different "Farmers' Days" held on the camps and are both on the sown pastures.

As outlined in previous publications (Hall, 1931: 203, and 1932: 389) P = 400 lbs. per morgen of a rock phosphate and superphosphate mixture, N = 200 lbs. sulphate of ammonia per morgen and K = 80 lbs. chloride of potash per morgen. When the experiment was started it was decided to apply the P. N and K once annually but extra nitrogen dressings were later found to be necessary for the best results.

Ca = 2,000 lbs. agricultural lime per morgen applied once in five years.

In camps 1 and 2 the PNK half of each camp was limed at the above rate.

The basal dressings as outlined, i.e., the P, K and one N dressing annually, were applied to the respective camps in June, 1931, April, 1932, February, 1933, November, 1933, August, 1934 and February, 1936. Extra nitrogen dressings in the form of sulphate of ammonia or nitrochalk were applied at the rate of 200 lbs. per morgen in August, 1933, August and November, 1934, in January, February and April, 1935, and towards the end of 1936-37 grazing season. In February, 1935, the grazing on the O and P camps, Nos. 7 and 8, and on the O and P strips of camps 1 and 2 was so poor that nitrogen dressings were applied. These two camps and the O and P strips of camps 1 and 2 thereafter received nitrogen dressings at the same time as the other camps and strips.

Grazing was carried out in rotation on these camps whenever there was sufficient grass for the animals. Dairy cows in milk usually constituted the "first line" or in other words were given the best of the grazing. The "second line" or "followers" were usually dry stock and heifers but mules and donkeys were also used on occasions to clean up the camps and consume tufts and rank herbage left ungrazed by the cows.

In each season of the five the pastures were harrowed at least once to distribute droppings and on one occasion were cultivated with a lucerne cultivator, but even when this was done four times to stir up the pasture effectively no benefit was apparent.

No botanical survey was carried out in these camps but the experiment was visited by the senior author at least once every season. On these occasions notes were made on the sward of each camp and the effect of the fertiliser treatments and management carefully studied. The botanical changes that took place and their significance will be discussed later.

Grazing Days.

The methods used in bringing the grazing records of the various types of farm animals to a common unit for the purposes of comparison were given fully in a previous publication (Hall, 1932: 390). The results of the five seasons, the dates of the beginning and termination of the grazing seasons and the number of completed rotations are given in Table II.

It will be noted that in two instances the grazing season was appreciably longer than the calendar year. This was due to the fact that the rainfall and climate at George are, generally speaking, in favour of grass growth all the year round and Mr. Leggett grazed his cows on the experimental plots whenever there was grass available for a full rotation. At the conclusion of a favourable period a local drought rather than the end of a season would bring the grazing season to an end.

TABLE II—Seasonal Grazing Returns.

Camp No.	Fertiliser Treatment.	Grazing Days per Morgen. 1931/32.	1932/33.	1933/31.	1934/35.	1935/36.	Average.	Increase over Control, 0 = 100.
1	O, P, PN and PNK in strips	538	214	258	415	324	350 ...	189·7
2	O. P, PN and PNK in strips	549	219	264	398	310	348 ...	188·7
3	PNCa	241	332	325	445	516	372 ...	201·6
4	PNKCa	278	304	350	469	547	390 ...	211·2
5	PNK	233	295	322	440	524	363 ...	196·7
6	PN	219	283	289	418	435	329 ...	178·3
7	P	169	190	156	293	292	220 ...	119·3
8	O	141	155	146	257	223	184 ...	100·0

	1931/32.	1932/33.	1933/34.	1934/35.	1935/36.
Grazing season began	1/10/31	3/7/32	26/9/33	7/10/34	20/7/35
Grazing season ended	16/ 6/32	27/7/33	10/7/34	12/ 7/35	14/8/36
Number of days in season	268	390	288	170	391
Number of rotations	9	14	9	6	6

Milk Records.

In order to obtain data to confirm the grazing day records all co-operators during the course of the experiments were asked to try to obtain milk records, beef cattle or sheep weights, but in practice it was found almost impossible to obtain accurate data of this nature. Co-operators either had no scales or did not record the yields of the milk cows. Mr. Leggett, however, tried on three occasions to provide comparative milk yields from the experimental plots and though the records of one rotation were not completed owing to sickness, his results are considered worthy of presentation. Difficulty was encountered in obtaining cows of more or less equal performance and of the same period in the lactation, but as the same cows when once in a group grazed on all the camps, the differences in yield between the cows is not of sufficient magnitude to obscure the results. The data obtained in this connection are presented in Tables III and IV.

Notes on the Rotations.

In rotation A the leaders consisted of four and the followers of six cows. No extra feeding was given; the rainfall during the previous twelve months was 24 inches instead of the expected 36 inches and the previous grazing was from 19th March to 11th April with fifteen cows in two groups. Of the four "leaders" the numbers of days in the lactation period at the time the test started were 215, 221, 95 and 80. The numbers of days for the followers were 107, 160, 215, 100, 145 and 155.

In B the grazing was started on the 7th October with seven cows in the leader group, but one came into milk only on the 13th, when the group was in camp 2. The numbers of days in the lactation period for the other cows were 359, 259, 258, 256, 245 and 105.

The leaders were fed brewers grains at the rate of 3 lbs. for every gallon of milk produced at the beginning of the rotation. Though it was relished at first, the cows soon tired of it and by the tenth day only two of the cows were receiving 3 lbs. each daily.

There was a very cold snap of weather from the 9th to 14th October with 2·78 inches of rain. Further rain fell on the 19th and 21st and after this wet, misty weather followed, bringing up the total rainfall to 4½ inches for October. The previous grazing was from 24th June to 10th July, 1934. Fertilisers had been applied on 26th August but September was dry, with only 2 inches of rain and grazing did not become available until 7th October.

The yield for camp 8 and the yields of the followers in this rotation are not given as they were not recorded.

In rotation C the leader group contained eight cows but one was not milked while the group was in camp 1. This rotation followed immediately after rotation B and no extra feeding was

TABLE III—Milk Yields in Gallons per Morgen (three rotations only).

Camp No.	Composition.	Fertiliser Treatment.	A. Rotation of April/May/June, 1934. Leaders.	Followers.	Total.	B. Rotation, Oct. 7-Nov. 3/34. Leaders only.	C. Rotation, Nov. 14-Dec. 13/34. Leaders only.	Average Milk Yield for All Rotations.	Percentage Increase over O.
1	4a Mixture -	Strip fertilised	21·6	20·2	41·8	44·5	86·2	42·8	262·7
2	3 Mixture -	Do. -	24·4	21·2	45·6	50·0	91·6	46·5	294·0
3	Kikuyu, Kentucky Blue grass and clover	PNCa -	26·2	17·2	43·4	38·9	88·7	42·8	262·7
4	Do. -	PNKCa -	19·5	19·0	38·5	64·8	70·6	42·4	259·3
5	Do. -	PNK -	19·0	14·7	33·7	65·6	70·4	40·6	244·0
6	Do. -	PN -	29·9	24·9	54·8	53·6	65·4	45·7	287·2
7	Do. -	P -	10·0	14·1	24·1	28·4	26·2	20·5	73·7
8	Do. -	O -	9·6	9·2	18·8	—	10·4	11·8	—

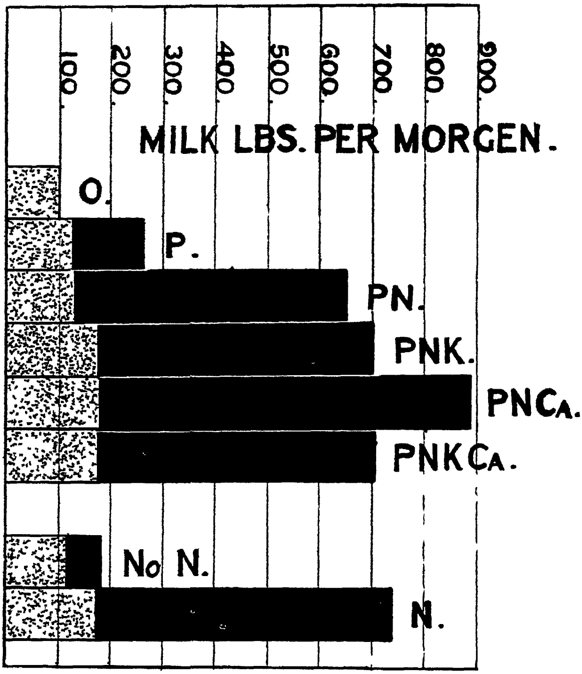

Fig. 1—A summary of the milk yields obtained in the second rotation, 14/11/34 to 16/12/34. The lighter portions represent the daily yields from the eight cows recorded in the rotation while grazing on the various treatments.

given. For most of the time in this rotation the followers were dry cows. Milking of the cows in all three rotations was done twice daily.

The fertilised pastures not only gave increased carrying capacity and far more milk per morgen but also increased the daily milk yields of the cows, as shown in Table IV.

In rotation A the camps were not grazed in numerical order as it was felt that there might be a carry-over effect if the cows grazed on a good camp, say, for three or four days then for one or two days on a poor camp. Mr. Leggett was, therefore, advised to start recording on unfertilised veld, lead up to the best camps and then record again on unfertilised veld. The camps were thus actually grazed in the following order : —(yields of leaders only).

Veld	. .	11·9 lbs.	Camp 6	...	14·9 lbs.
Camp 8	. .	12·0 ,,	Camp 3	...	13·1 ,,
Camp 7	. .	12·5 ,,	Camp 5	...	11·8 ,,
Camp 1	...	13·5 ,,	Camp 4	...	12·1 ,,
Camp 2	...	15·2 ,,	Veld	...	8·8 ,,

TABLE IV—Average Daily Milk Yield per Cow in Lbs.

Pasture.	Treatment.	A. Rotation, 24/4/1934-5/6/1934. Leaders.	Followers.	Average of All Cows.	B. Rotation, 7/10/34-3/11/34. Leaders only.	C. Rotation, 14/11/34-13/12/34. Leaders only.
Veld	0	11·9	8·1	9·63	—	—
Camp 1	Strip fertilised	13·5	8·4	10·45	18·5	24·6
Camp 2	Strip fertilised	15·2	8·8	11·40	19·2	22·9
Camp 3	PNCa	13·1	7·1	9·87	18·5	22·1
Camp 4	PNKCa	12·1	7·9	9·60	18·5	22·0
Camp 5	PNK	11·8	4·8	7·31	18·7	22·0
Camp 6	PN	14·9	8·3	10·96	19·1	20·4
Camp 7	P	12·5	7·8	9·26	20·3	16·4
Camp 8	0	12·0	7·7	9·42	—	13·0
Veld	0	8·8	4·8	6·46	—	15·1

Mr. Leggett observed during the course of this rotation that drought conditions extended through April and May and the pastures suffered as the rotation progressed. The grass became dry and of little value for milk production. The condition of the animals improved considerably, however, and in spite of the dry weather reducing the milk yield of the cows, they continued to improve even when the milk yield dropped about 15th May.

In rotations B and C the camps were grazed in numerical order. After grazing in camp 8 in rotation C the leaders grazed for three days in good, unfertilised Rooigras veld. In this rotation Mr. Leggett remarked after camp 5 had been grazed:

"Lack of moisture is beginning to show at this stage—grass is in good condition but not as succulent as No. 3 when that camp was grazed."

Similarly, when the cows were grazing camp 6, he observed:

There is now a definite falling off in the quality of the grazing; it is plentiful and appears good, but though the cows fill well, it does not supply the milk."

Discussion.

Grazing Days.—The grazing day returns show that there has been only a small response to phosphate in this area, although the sward contained appreciable amounts of clover. Furthermore, nitrogen applications on the phosphate treatment subsequent to February, 1935, improved the grazing so that the average increase given by phosphate only is actually lower than that shown in the table, namely 19·3 per cent.

With regard to the other treatments nitrogen appears to be the important fertiliser constituent and the yields of all camps receiving N (with phosphate) show no important differences. As there are only six comparable camps on kikuyu grass it cannot be said that the difference of about 10 per cent. between the average of camps 3 and 4 (PNCa and PNKCa) as compared with 5 and 6 (PNK and PN) is significant in favour of the lime dressing or between 4 and 5 as compared with 3 and 6 (7·4 per cent.) in favour of potash. These differences are probably not significant.

It should be pointed out that up to February, 1935, one quarter of both camps 1 and 2 received no nitrogen, one eighth no phosphate and one half no potash. Had nitrogen been applied to the whole camp in each case from the inception of the experiment the average results would probably have been better than those of the PN and PNK kikuyu camps.

Milk Records.

It was unfortunate that circumstances did not permit of milk records being taken over a whole season to give an idea of the annual productive capacity of fertilised kikuyu in the

George area. The increases shown in Table III, however, indicate that milk yields per morgen were improved on the PN and PNK plots to the extent of nearly 300 per cent. and in the second rotation even more. If the three rotations recorded in 1934 may be taken as representative of most, if not all the rotations, it may safely be assumed that fertilising improved pastures in this area and will give increases in the milk yield per unit area of from 100 to 300 per cent. and even more. The milk yields also show up the value of the pastures more than grazing-day returns and indicate the importance of getting some evaluation from production. Thus even phosphate alone has given a worth-while increase in milk production of 73·7 per cent. on the average.

ECONOMIC BENEFITS.

An economic consideration of the milk yields is not easy, as these were not obtained over a full season, but, judging from the length of the grazing season obtained, we are justified in considering an average grazing year of about 300 days. On this basis we calculated from the milk averages that the PN camp produced 457 gallons and the O camp 118 gallons per morgen. The difference, 339 gallons, at 4d. is £5 13s. PN, the cheapest fertiliser treatment, cost £3 9s. 5d. per morgen on the farm, approximately 4s. 1d. per 100 lbs. for phosphates and 9s. 1d. per 100 lbs. for nitrochalk. This leaves a difference of £2 4s. 7d. per morgen in excess of fertiliser costs without taking into consideration other obvious benefits to the health, condition and growth of the animals and the amount saved in concentrates. This amount of milk is low compared with the 1,000 to 1,200 gallons per acre obtained at the Cedara School of Agriculture, but here fertilising was twice as heavy and the camps were grazed by cows of high productive capacity. It would appear that if the full benefit is to be obtained from intensive pastures, heavier fertilising and better cows will be essential.

INDIVIDUAL MILK YIELDS.

It is more difficult to prove that fertilised pastures increase the individual milk yields as well as the carrying capacity for the natural tendency is for the yield to decrease as the lactation progresses. Furthermore, if grazing rotation extends over a period of three or four weeks, as was often the case in this experiment, changes in weather conditions will cause corresponding changes in the herbage and these variations will tend to overshadow or obscure the effect of the herbage on milk flow.

Nevertheless, the average daily yields per cow as shown in Table IV indicate that the fertiliser treatments containing PN and PNK have had very definite influence on the daily milk yield. They also indicate that unfertilised veld in this area is inferior to fertilised exotic pastures from the milk production point of view and also inferior to the unfertilised kikuyu.

Botanical Changes.

It has previously been stated that a comprehensive grass and clover mixture was sown in camp 1 at the beginning of the experiment, a somewhat simpler mixture in camp 2 and a mixture of kikuyu grass, Kentucky Blue and wild white clover in camps 3 to 8.

In October, 1931, approximately six months after sowing, it was noted in both camps 1 and 2 the PNKCa strips were outstanding as regards density of sward and cover. In camp 1 Yorkshire fog and Rescue grass were very good, with cocksfoot, Kentucky Blue grass, perennial rye and subterranean clover distinctly promising. Wild white clover and sheeps burnet were present but were not conspicuous. Apparently there was no trace of the other 16 species of the mixture even at this early stage. It was found later that the percentage germination of a number of these grasses was very poor.

In camp 2 Yorkshire fog and Rescue grass were the dominant species. Rye grasses were also present in fairly large amounts and some cocksfoot was reported as being present in the sward. It was not included in the original mixture but may have been introduced as an impurity or been blown in from camp 1.

In the six other camps good stands of kikuyu were obtained and also of clover and Kentucky Blue grass. However, an unusually severe frost about 26th July, 1931, seemed to have killed out most of these two species.

In January, 1932, Mr. Leggett was sent 6 lbs. of New Zealand wild white clover, 3 lbs. dwarf white clover, 3 lbs. Chilean red clover, 6 lbs. subterranean clover, 3 lbs. alsike clover and 3 lbs. yellow trefoil, along with a bottle of inoculant. These strains were mixed, inoculated and sown on the six kikuyu camps towards the end of March, 1932.

Notes taken in November, 1932, showed that of the two mixtures on camps 1 and 2 that on camp 1 was superior. Yorkshire fog was dominant with satisfactory growth of herds grass, white clover, trefoil and subterranean clover. The complete fertiliser strips with lime were outstanding but growth on the controls was poor. At this time the cover of the kikuyu camps was still considered poor.

A year later—November, 1933—careful notes were taken on the distribution of species on the strips of camps 1 and 2.

Camp 1.—PNKCa—plenty of wild white clover, herds grass, *Paspalum dilatatum*, cocksfoot, trefoil and a little subterranean clover. Not nearly as much Yorkshire fog as in camp 2 but more cocksfoot.

O—poor cover. Herds grass, Yorkshire fog, *Paspalum dilatatum*, Italian rye, sweet vernal and a small amount of clover present.

P—similar to O but with more clover.

PN—far better than the P strip. The same species and also some *Poa pratensis* and a trace of sheeps burnet present.

Camp 2.—PNKCa—Yorkshire fog dominant and a good thick cover. Small amounts of cocksfoot, sweet vernal, perennial rye, wild white clover and trefoil present.

O—poor but, if anything, better than P.

P—poor.

PN—Yorkshire fog dominant, a little cocksfoot and slightly more sweet vernal and trefoil present.

It will be noted that sweet vernal *Anthoxanthum odoratum* was present in both camps although not originally sown in either. It had probably been sown in very small amounts as an impurity and had increased.

In the case of the six kikuyu camps *Poa pratensis* was now in evidence in camps 3, 4, 5 and 6, particularly in camps 5 and 6. In No. 5 it was growing strongly, particularly in all urine patches. Much trefoil was growing in 6 and also subterranean and red clovers. White clover and trefoil were good in camp 5, but no red clover was seen. Camp 4 had plenty of *Poa pratensis* but being drier than the other camps had less clover, while in camp 3 no clovers were seen. Camp 7 had more white clover than 8 and also had some subterranean clover at one end. No *Poa pratensis* was in evidence in these latter two camps.

In January, 1936, almost five years after the original seeding and planting, conditions were very dry but the two sown camps were looking better than the six kikuyu camps and contained more clover. The species present in the two camps in order of prominence in the sward were:—

Camp 1.—4a Mixture: Paspalum dilatatum, herds grass; cocksfoot and wild white clover equally prominent; Yorkshire fog, sweet vernal.

Camp 2.—3 Mixture: Yorkshire fog, wild white clover; cocksfoot and sweet vernal equally prominent.

"Of the kikuyu camps 7 (P) and 8 (O) are very poor, while in 3 (PNCa), 4 (PNKCa) and 5 (PNK) *Poa pratensis* now appears to be ousting the kikuyu entirely."

When the experiment was visited again in March, 1937, it was found that Mr. Leggett had been in hospital for about seven months. The camps had been neglected and overgrazed but in the two sown camps *Paspalum dilatatum* and Yorkshire fog were still very much in evidence. The *Poa pratensis* was not quite so prominent in the kikuyu but there were some good patches of clovers to be seen.

In an experiment with similar mixtures on Mr. I. B. Whitehead's farm near Greenbushes, Port Elizabeth, under drier conditions the dominant surviving grasses after three years were

Rhodes grass, *Paspalum dilatatum*, herds grass and Yorkshire fog. Kikuyu did not do so well here but *Stenotaphrum secundatum* was more drought-resistant and more promising. In a mixture test on Mr. D. Dold's farm at Trappes Valley near Grahamstown, these same four species survived all others but subsequently Rhodes grass and *Paspalum dilatatum* did best.

In March and April, 1936, another five-acre paddock was added to Mr. Leggett's experiment, the work on which was to have been carried out in co-operation with the Extension Officer, Mr. O. A. Langenegger. The seed sown was 50 lbs. *Paspalum dilatatum*, 50 lbs. Akaroa cocksfoot, 35 lbs. German fescue (*Festuca elatior*), 15 lbs New Zealand tall fescue, 10 lbs. New Zealand wild white clover, 7 lbs. *Poa pratensis* and 5 lbs. Yorkshire fog, together with dressings of ½ ton lime, 100 lbs. nitrochalk and 200 lbs. superphosphate per acre. Subsequently certain areas received in addition 100 lbs. muriate of potash per acre.

In March, 1937, the fescues, cocksfoot, Yorkshire fog and clovers were most in evidence. A small amount of *Paspalum dilatatum* was present but it had evidently been slow in germinating.

In May, 1938, after this and the other pastures had been neglected for a year, during which time no fertilisers were applied and continuous severe grazing took place, an estimation of the botanical composition was made. After this severe test it was found that on the 5-acre paddock the fescues and fog had decreased and cocksfoot and *Paspalum dilatatum* had increased, the botanical composition being cocksfoot 33·3 per cent., wild white clover 20 per cent., Yorkshire fog 18·3 per cent., *Paspalum dilatatum* 8·3 per cent., kikuyu 5 per cent., tall fescue 3·3 per cent. and *Poa pratensis* 1·6 per cent.

In the original experiment, camp 1 contained 55 per cent. *Paspalum dilatatum*, 40 per cent. of a Sporobolus species and 5 per cent. white clover, with traces of Yorkshire fog and cocksfoot. Camp 2 consisted of 95 per cent. Sporobolus species and *Cynodon dactylon* (kweek), with 5 per cent. Yorkshire fog and white clover. Here and there in this camp patches of *Paspalum dilatatum* had become established. In the six kikuyu camps kikuyu was still the dominant grass though it had been invaded by a local species of Sporobolus. Camp 3 (PNCa) contained 1 per cent. wild white clover, 1 per cent. *Poa pratensis*, 2 per cent. *Cynodon dactylon*, and a few small areas of *Paspalum dilatatum*. Camp 4 (PNKCa) had more *Paspalum dilatatum*—about 2 per cent.—but less white clover and traces only of *Poa pratensis* and *Cynodon dactylon*. In camp 5 (PNK) the kikuyu was more open and contained more weeds and Sporobolus. White clover amounted to 2 per cent. and *Cynodon dactylon* to 1 per cent. with traces of *Paspalum dilatatum* and *Poa pratensis*. Camp 6 (PN) contained 1 per cent. each of white and subterranean clovers at the lower end of the camp and a trace of *Poa pratensis*.

Both camps 7 (P) and 8 (O) contained more Sporobolus species and less kikuyu than the others, but No. 7 contained 1 per cent. white and subterranean clovers and a trace of *Poa pratensis*, while camp 8 had more local weeds and only traces of clovers and *Poa pratensis*.

It will be noted that in spite of two years' neglect and over-grazing kikuyu, *Paspalum dilatatum*, Yorkshire fog, cocksfoot, *Poa pratensis* and white and subterranean clovers have shown remarkable persistence.

Fertilisers and Palatability.

The influence of fertilisers on palatability has been noted by many observers but a direct correlation is very hard to establish, as it involves watching the grazing animals for long periods and hence consumes more time that the observer can usually spare. In this case, however, Mr. Leggett proved to be a keen observer and studied the grazing habits of his animals over a period of more than five years. Some of his observations are, therefore, quoted here as being of value in connection with the establishment and utilisation of improved pastures.

The first observation of this phase was made in January 1932, when Mr. Leggett remarked as follows: " At 4 o'clock every afternoon for five days the position of the grazing cattle was noted and it was found that, except on one day when there were four cows grazing on the PN portion, all the cattle—8 cows and 1 bull—were at that moment grazing on the PNKCa portion of the sown camps. Also when driven into these camps after milking they invariably walk right through the various treated portions down to where the complete fertiliser was used."

Again in June, 1932, it was remarked that the preference shown by the cows for the complete fertiliser treatment was being fully maintained, particularly by the cattle in the " leader " group.

In July, 1932, it was noted that the cows showed no readiness to graze camps 7P and 8O and although there appeared to be ample grazing for two days, they were kept in only one day in each case.

A note on the rotation ending 4th April, 1933, was to the effect that those portions of camps 1 and 2 receiving the complete dressings of fertilisers are very superior to the remainder; growth is much more pronounced, and there is a much better sward. Also the cattle spend at least 75 per cent. of their time on those better portions.

For the next three years Mr. Leggett continued to record his observations on preferences for certain fertiliser treatments but space will not permit of more attention being given to this aspect of pasture improvement. In April, 1936, however, Mr.

Leggett summed up his observations on this point and his remarks are deemed worthy of record. He states: "I have previously drawn attention to the non-selective grazing by animals in the camps; there is no selection as the term is understood when it applies to different grasses, but there is a big preference shown for certain fertiliser treatments. I have also remarked about that aspect in former rotation reports, but I have never seen it so emphasised as on the present occasion.

For the past two months all the cattle have been grazing on veld. They were, therefore, hungry for grazing of a superior quality yet when put into the mixed pasture camps which receive four separate fertiliser treatments in sections, they took no notice whatever of either the P or the PN treatments but walked right through those to the PNKCa sections and this in spite of the fact that the grazing on the PN portion was really good.

On 10th April, that is at the end of the second day in camp 2, the PNKCa section had been well grazed down but I could find no trace of any grazing having been done on the other sections of the camp. Going from there to campl, I found that the followers—cows, calves and mules—had grazed more on the completely fertilised portion than they had on the rest of the camp, in spite of the fact that the 10 leader cows had grazed the best of it for four days previously.

This display of preference for certain treatments needs to be seen to be believed. All that I have said about it seems inadequate and does not convey the impression I would like to create."

Health of the Animals.

Mr. Leggett makes frequent references in his reports to the good condition his cows were in compared with what they were before the experiment started, and also compared with those of other farmers in the vicinity. He states that the cows were able to keep up their condition in droughts when growth on the camps was not sufficient to maintain milk yields. In June, 1933, he reports: "During the last eighteen months there has not been one case of retention of the afterbirth, whereas prior to the cows having access to mineralised sweet pastures this trouble was frequently experienced."

Summary.

An experiment with fertilised sown pastures in the George-Knysna area is described over the period 1931-1938. Grazing day records were obtained for five complete reasons, and in 1934 milk yields were recorded for three rotations. Periodical visits were paid to the experiment to note the extent and direction of botanical changes and detailed observations on the influence of fertilisers on the palatability of the grass species and of the grazing on the health and condition of the cows were made by the co-operator.

Two seed mixtures were tried in comparison with a mixture of kikuyu, *Poa pratensis* (Kentucky Blue) and clovers. The sown mixtures gave very good results for the first two seasons, and on the average would probably have proved superior to the kikuyu mixture had the camps been given a complete fertiliser mixture over the whole camp.

Phosphate only gave an average increase of 19 per cent. in grazing days per morgen over the no fertiliser treatment camp.

The best response was obtained from nitrogen dressings and all treatments containing nitrogen gave increases in grazing days of from 78·3 to 111·3 per cent. over the no fertiliser treatment. Lime and potash produced small increases but their significance is somewhat doubtful.

Milk records from three rotations in 1934 showed that fertiliser treatments markedly increased the returns per morgen and to a smaller extent increased the yields per cow. On the average phosphate only increased the milk yield by 73.7 per cent. while nitrogen and phosphate together gave increases of from 244 to 287 per cent. over the no fertiliser treatment. On the two sown camps which were fertilised in strips, milk yields were increased by 262 and 294 per cent.

These results indicate plainly that the primary needs of pastures in this area are phosphates and nitrogen, and lime and potash do not give such marked responses. As a result, the number of nitrogen dressings was increased and in the last year of the experiment the O and P camps and the O and P strips in camps 1 and 2 were given applications of nitrogen. From camp 6, phosphate and nitrogen, the results appear to justify the use of 400 lbs. of a mixture of superphosphate and rock phosphate plus 600 lbs. per morgen of nitrochalk in three dressings. The cost of this was £3 9s. 5d. per morgen on the farm and the extra milk produced, calculated at 4d. per gallon, worth £2 4s. 7d. more than the cost of the fertiliser. There are other benefits to be considered, such as the better health and growth of the stock and a saving of concentrates.

Periodical inspections showed that kikuyu grass, *Paspalum dilatatum*, Yorkshire fog, cocksfoot, *Poa pratensis* and wild white clover and subterranean clover are persistent and valuable herbage plants for this area. Tall and other fescue grasses have not done as well under the condition of this experiment as the foregoing.

Observations made by the co-operator showed clearly that the complete fertiliser treatment with lime gave the most palatable grazing. When the cattle had the choice they almost invariably grazed the fully fertilised pasture first. The co-operator also noted that the fertilised pasture improved the condition of the cattle, which were always in better condition than those in the neighbourhood. When on the pastures also there was less trouble due to retention of the afterbirth.

This experiment shows that the George-Knysna area is potentially a good one for pastures provided due attention is given to grass species, soil fertility and pasture management.

ACKNOWLEDGMENTS.

The writers wish to acknowledge their indebtedness to Mr. F. W. E. Leggett for his enthusiastic and sustained interest in the experiment, as shown by his careful records and copious notes and observations. Although incapacitated by severe illness in 1936 and 1937, Mr. Leggett never lost his interest in the experiments nor his enthusiasm. Our thanks are also due to Mr. S. M. Murray for working up the grazing records.

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INTENSIVE GRAZING ON VELD—V; KENYA.

The Effect of Rotational Grazing and Fertilisers on Carrying Capacity and Milk Yields over a Five-year Period

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A NEW APPARATUS FOR CHARTING VEGETATION

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With 1 Photograph and 1 Text Figure.

Read 5th July, 1938.

In the study of vegetation, accurate charting of the flora is often essential. Up to the present, two types of instrument have been employed—the pantograph and the camera recorder.

All the pantographs hitherto employed possess common defects. They require careful readjustment for each and every chart: they are clumsy to move: they require two operators. On the other hand, the camera recorder, as described by Rowland and Hector, is easy to handle and requires little or no adjustment. It suffers, however, from two defects:—1. Two operators, the one to indicate and identify the vegetation, the other to trace the vegetation, are required. 2. The second operator, charting the vegetation, may only too frequently suffer from eye strain and heat fatigue.

As a consequence, an attempt was made to devise an instrument which would require but one operator, eliminate as far as possible eye strain and heat fatigue, and at the same time be both accurate and rapid in action. The following instrument—which might be described as a " direct-acting " pantograph and is known as the " Puniv charter "—is claimed to possess these features.

The apparatus consists essentially of two horizontal rigid 12in. square plates, C^1 and C^2, 9 inches apart from one another. (Diagram 1 and Photograph 1.) The under-surface of the upper plate (C^1) must be smooth and constitutes the tracing surface. The lower plate (C^2) is cut out in the centre and so forms the upper " socket-bearing " for a ball, O.

The lower "socket-bearing" for this ball consists of a third plate, 6 inches square, its centre cut away as in C^2, and bolted thereto by four adjustable bolts so that the distance between the two is approximately 1-2 inches, depending on the size of the ball, O ($1\frac{1}{2}$-$2\frac{1}{2}$ inches) As a consequence, the ball, together with the plates C^2 and D form a "ball-and-socket" universal joint.

Through the ball there passes a $\frac{3}{4}$in. metal tube, H, projecting 5 inches above plate C^2 and $26\frac{1}{2}$ inches below plate D. Into the upper end of this tube or arm there is fitted a plunger B (over-all length $6\frac{1}{4}$in), whose free end ($1\frac{3}{4}$in.) tapers to a neck carrying the tracing point—a $\frac{1}{8}$in. ball point: its lower portion moves freely within the tube, but is pressed by means of a spiral spring, I, against the face of the tracing plate, C^1. Withdrawal of the tracing point from the plate, however, may be secured at any moment by the cord, K, attached to the lower end of the plunger and passing down through the centre of the spring to an opening in the tube H at the point K. From this point the cord passes through guides to an operating lever, L.

A second plunger, M, $13\frac{1}{2}$in. in total length, is inserted at the lower end of tube H. It can be drawn out against the tension of a second spiral spring, J. Its free end tapers to a point. When this plunger is withdrawn some 3in. from the enclosing tube H, and is within about 1in. of the ground surface, and the upper plunger B is resting on the tracing surface, the ratio of the two arms is 4 to 1. This ratio, however, may be altered at will, by raising the upper plate L, on its four supporting columns

The whole apparatus is carried on 3 (or 4) rigid legs hinged to the plate C^2 or D.

In operation, a quadrat frame of say 50 sq. cms. is centred below the apparatus. The squared tracing paper is then drawn from roller A across the tracing face of plate C to roller A^1 and a sheet of carbon paper is inserted between this and the surface of the tracing plate, its copying side in contract with the tracing paper. Finally a sheet of linen paper is stretched *below* the tracing paper and all three kept in place by means of the frame Q and spring catches R. All the papers are thus in close contract with plate C.

Meantime the plunger B is swinging free from the plate C by the tension on cord K, the lever L being in the down position. The plunger-pointer M is then pulled out and the arm swung until the point touches the inside edge of the quadrat Lever L is raised: the plunger B comes into firm contact with the tracing surface: the pointer M is then drawn round the square

whilst the tracing point outlines the square. Lever L is again lowered withdrawing the tracing point from the paper. The pointer M is then orientated to the first grass tuft: the lever is again released and the pointer arm is swung round the area of the tuft and the first area thus recorded. In this manner the area of every tuft is accurately traced and identified by a symbol. Further, if the neck of plunger B be attached to a standard planimeter—resting on a plate about 1in. below and to one side of plate C^1, the areas traced may simultaneously be measured.

In practice some workers find it expedient to first trace the outline of the plants in the quadrat, then remove the tracing and identify the species separately.

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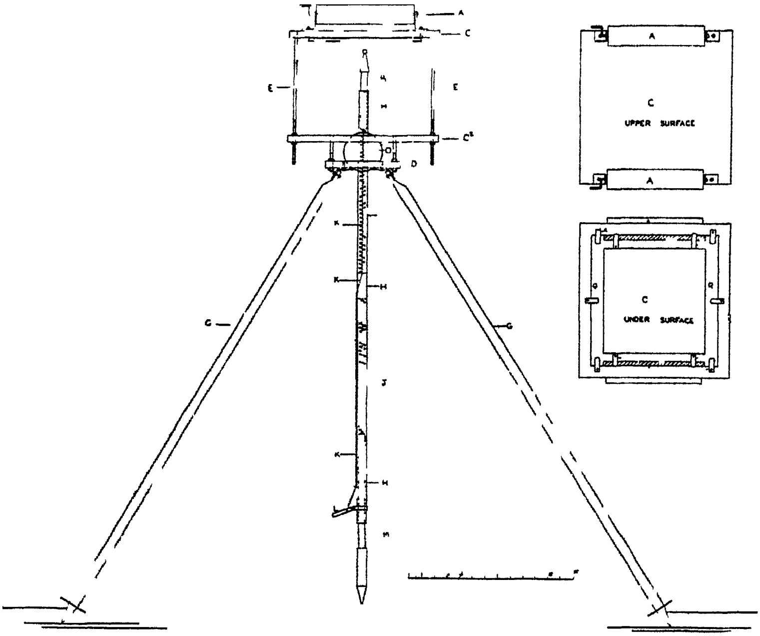
[*Photo. J. M. Hector.*

¼ meter Charter in Operation.



EXPLANATION OF DIAGRAM I

A—A 1½in roller supported on two metal brackets so that it is ½in clear of the top of plate C. A handle is inserted at one end of the roller to facilitate operation. Tension is provided for by a screw (with tension washer) at the other end. Two such rollers are fitted as shown—projecting about ½in beyond the face of plate C^1, by means of these the paper on which the vegetation is to be traced is moved into position as desired. (These rollers may be omitted.)

C^1—A 12in square metal plate about ⅛in thick and polished on the under surface. To its under surface the frame Q is attached centrally by means of spring clips R. Plate C^1 is rigidly fixed at the required distance (here 9 inches) from plate C by means of four metal rods E—long threaded at the lower end to provide for the alteration of this distance.

C^2—A plate similar to C^1 but cut away in the centre so as to form the upper socket-bearing for the ball O.

D—A 6in square ⅜in metal plate cut as in C to form the lower half of the socket-bearing for the ball O. It is attached as shown by means of four bolts to plate C—the bolts giving the necessary tension.

O—is the ball already referred to which together with the two plates C and D forms a "ball-and-socket" universal joint. A ball 1¾-2½ inches in diameter is suitable.

G—the legs of the tripod on which the instrument stands. They are hinged as shown to the lower face of plate C or D. The lower end of these legs bear a disc about 1½in from the sharpened points to ensure steadiness on soft soil.

H—A ⅝in metal tube of good rigidity passing through ball C—projecting 4½in above plate C and 26½in below plate D.

B—A plunger B, 6¼in. long, accurately fitting into the upper end of tube H. The lower 4½in. moves freely but perfectly within tube H under the pressure of a spiral spring I, which presses the point of the plunger with a force of approximately 1 lb. (one pound) on to the paper against the lower face of plate C¹. The upper 1¾in. of plunger B is tapered off from about ⅜in. at the base to a narrow neck carrying a ⅛in. tracing ball point. Withdrawal of the point from the paper is secured by means of a cord K attached to the lower end of plunger B, passing down through the centre of the spring to an opening in tube H at point K. From this point the cord passes through guides to lever L.

M—A second plunger, operating in the lower end of tube H. It is here 13½ inches in total length—the upper 9 inches being a perfect sliding fit in tube H. under the influence of spiral spring J in tension. The lower 4½ inches is parallel for the first three inches, but tapers for the remaining 1½ inches to a point.

Q—A frame having a central opening 8 inches square within which the point of plunger B operates. The frame consists of two plates, 3/32 inch in thickness, which grip between them a section of strong linen-cloth and in turn are securely fixed, centrally, to the underface of plate C¹ by means of spring catches R so placed as to let the tracing paper pass freely between them and between frame Q and plate C¹. To the underside of this frame carbon paper is fixed and held securely by means of a strip of metal T on which spring catches R press.

EFFECT OF LEAD ARSENATE AND COPPER CARBONATE SPRAYS ON CITRUS FRUITS

BY

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Read 8 July, 1938.

ABSTRACT.

No evidence was obtained of any effect of lead arsenate on the total soluble solids in the fruit juice. Copper carbonate, applied in five cover-sprays at the total rate of 5 ounces per large tree, showed influence on neither the total soluble solids nor the acid content of the juice from sprayed trees. A slight earliness in colouring of the fruit sprayed with this material was observed. Chemical analyses showed that the quantity of arsenic present in the fruit juice, following cover-sprayings with lead arsenate, was negligible. No increase in the lead or copper content in the fruit juice, above that normally found, resulted from cover-sprays of lead arsenate and copper carbonate.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 236-243, December, 1938.*

SUB-SURFACE EROSION ON A NATAL MIDLANDS FARM

BY

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With 4 Text Figures.

Read 5 July, 1938.

INTRODUCTION.

The soil erosion studies described in this paper were carried out on Major R. Tomlinson's farm, "Sheltered Vale," near Rosetta Railway Station, Natal. We wish to express our thanks to Major and Mrs. Tomlinson for their kindness and hospitality, their interest and the facilities they provided for our work. The expenses in connection with the survey of the area were borne by a grant from the Union Department of Agriculture. We wish, also, to thank Miss A. Taylor for the preparation of Figs. 2, 3 and 4.

GENERAL FEATURES.

The farm, about 2,500 acres in extent, is situated in a deep bend of the Mooi River below the Strathern Falls. It was allotted and surveyed in 1865, and since then has been used for both cattle and sheep and a small portion for general agriculture Several plantations of exotic trees, including *Eucalyptus viminalis, Pinus insignis, Pinus spp., Cedrus deodara, Cupressus lusitanica, Acacia mollissima, A. dealbata,* and *Populus alba* have been established at different times. The altitude varies from 5,500 feet in the highest part to 4,680 feet in the lowest.

The highest portion is a bow shaped sandstone ridge which rises abruptly from the Mooi River and is almost parallel to the river course. From this ridge a number of steep sided spurs extend towards the north and east into the lower lying parts. The general appearance of the farm is of cliff-like sandstone ridges with intervening valleys which widen and open out into the more even ground in the north-east.

Geologically, the farm lies in the Beaufort Beds of the Karroo Series. These beds consist of more or less horizontally stratified sandstones and shales (Du Toit, 1926), the latter predominating and the former being responsible for the productions of the ridges and spurs. Dolerite dykes and sills are not a conspicuous feature, but are of some importance in modifying the texture and the depth of the soil in the regions where they occur.

The sandstone gives a light grey, fine, sandy soil. On the tops of the cliffs and ridges the soil is shallow except in certain

pockets. In some cases the surface soil is sandy, in others there is a clay-loam surface soil below which lie successive horizons of porous sandstone and clay. On the edges the sandstone cliffs are eroded back in the form of ledges, and the disintegrated sandstone is added to the more clayey soil of the valleys. The valley soils are also light coloured, and are fairly compact and deep and less porous than those of the ridges. The colour of all soils is subject to considerable variation according to the proximity of the dolerite.

It would seem that the sandstone of the ridges is very porous, as is indicated by the number of permanent or intermittent springs and seepage areas which occur at the bases of the cliffs and slopes.

The farm is within the grassland zone of the Natal midlands, which is climatically unsuited for tree growth. The grass cover on the whole is good, although largely of a tufted nature. In common with other parts of the Natal grassland, the dry grass is burnt periodically in winter. At present there is no overstocking of the farm, but this may not have been the case in former years.

The plantations of exotic trees are generally poor, the trees being stunted, and many losses have occurred owing to the unfavourable environment. In particular, trees growing in soil overlying sandstone appear to suffer through the rapid percolation of rainwater to beyond the reach of the roots.

The rapid percolation of water through the sandstone is stressed since it seems to be an important contributive factor to the sub-surface erosion which is described later.

SUB-SURFACE EROSION.

Sub-surface erosion was studied over the whole farm, but particular attention was given to the eastern part between a high sandstone ridge and the Mooi River. A map of the area is given in Fig. 1. It will be seen from the map that the eroded area lies on the gentle slope between the sandstone ridge and the river.

The interesting feature of this erosion is the development of long underground water channels. These channels may attain a diameter of several feet. Eventually the roof of the channel becomes so thin that it falls in. A small portion may fall in producing a sinkhole into the channel, or a considerable length of the channel may fall in thus exposing a gully.

These channels are produced by the enlargement of underground fissures by the mechanical action of flowing rainwater resulting from periodic downpours of high intensity, and are a form of erosion quite distinct from that originating on the soil surface. The only reference we have been able to trace to this type of sub-surface erosion is the recent summary by Jacks and Whyte (1938, p. 60) of Thorp's account of sub-surface erosion of loess soils in China. The effects of sub-surface erosion in

Natal are such that we consider that the phenomenon as it occurs under our conditions warrants further discussion.

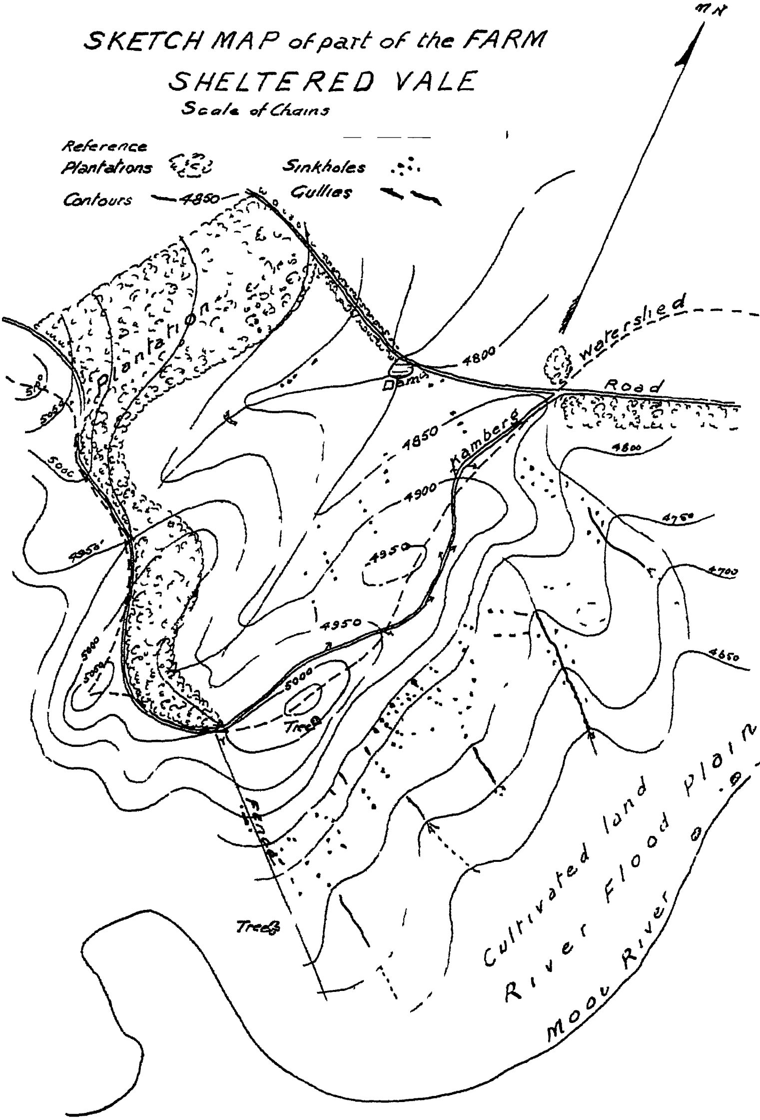

Fig. 1.—Map of the Area

Life History of Sub-Surface Channels.

Development.—The whole soil is deeply honeycombed by an anastomosing system of vertical cracks, which are undoubtedly

formed by shrinkage as the subsoil dries out. During heavy rainstorms these cracks form passages along which water flow occurs, with the result that the lowest parts of the cracks are widened by corrasion and undercutting of the sides, and develop eventually into large and regular water channels.

Course of Sub-surface Channels.—The course of the channels is naturally downhill, but is not determined, as would be the case with surface erosion, by the detailed surface topography, but by underground conditions, such as the degree of saturation and varying porosity of the subsoil and the position of the cracks. Soil cracking is more pronounced in places from which ground water is more easily drained, and occurs to a lesser extent in surface depressions in which the saturation of the subsoil is greater. As a result, sub-surface channels are often developed on either side of surface depressions and at a higher level than the lowest part of the depression. In the earlier stages of the erosion process the present surface depressions may have formed part of the same anastomosing system as that of the side channels, and thus represent the end product of the process.

Development of Sinkholes and Gullies (Dongas).—At first the channels are entirely underground, but when the roof is thin enough it commences to fall in, producing one or more sinkholes. Eventually as a result of more extensive collapse an open gully or donga is produced. In such cases the opening of the main channel is found at the head of the donga, and frequently subsidiary channels open into its sides.

A diagram of the formation of sinkholes and of a gully is shown in Fig. 2.

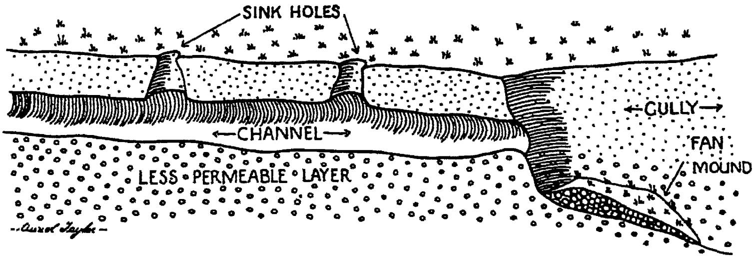

Fig. 2.—Diagram illustrating the formation of Sinkholes and of a Gully.

It was noted that whenever an open gully is formed, invasion and reclamation by grasses is fairly rapid, and much material eroded out of sub-surface channels is held up below the channel opening in the form of a fan mound, so that surface erosion is apparently a slower process than is sub-surface erosion.

Development of Fan Mounds.—Occasionally the lower end of a channel opens on to the natural soil surface. When this happens the suspended and transported material is deposited as a result of loss of velocity. Reclamation of this material by

grasses and sedges produces a fan mound. These mounds always carry a vigorous growth of herbaceous vegetation, and again indicate that in this area surface erosion is a slower process than is sub-surface erosion.

Fan mounds occur also when a sub-surface channel opens into a gully, as well as at the lower end of gullies which debouch on to the natural soil surface.

A fan mound is illustrated diagrammatically in Fig. 3.

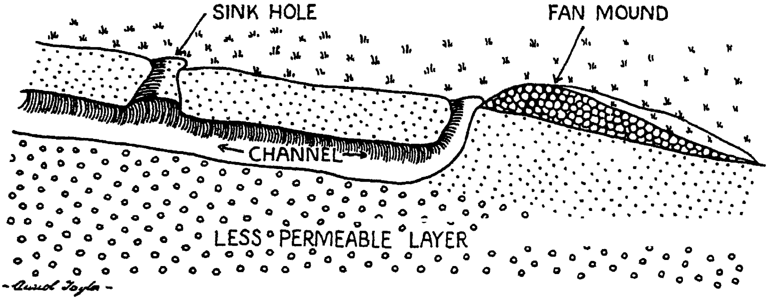

Fig. 3.—Diagram illustrating the formation of a Fan Mound.

Development of Cone Mounds.—When the lower end of a channel opens on to flatter ground, the load is deposited all round the opening, resulting in the development of a cone shaped mound. This is illustrated diagrammatically in Fig. 4.

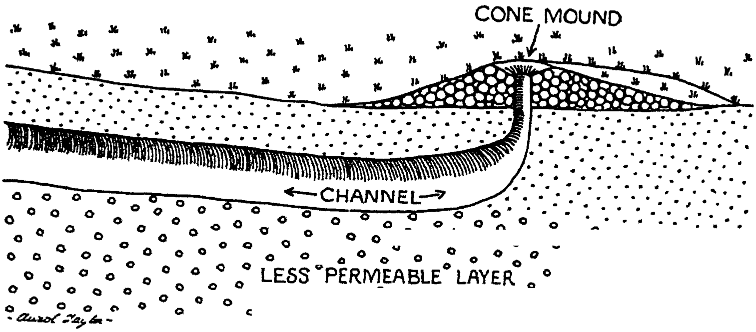

Fig. 4.—Diagram illustrating the formation of a Cone Mound.

The Channels in Operation.—When surveying the area during the summer, one of us had the opportunity of visiting the channels immediately after a heavy storm. It was clear that a large volume of water had poured out of the channel openings, and they were still in eruption during the visit. The quantity of material deposited was unexpectedly small, but the area over which deposition was taking place was greater than would be expected from a cursory study of the mounds during a dry period.

Causes of Sub-Surface Erosion.

The primary cause of sub-surface erosion is the development of vertical cracks as a consequence of soil shrinkage during drying out. In this connection the uneven distribution of the rainfall is an important factor. Rainfall records for Rosetta are available for the seven year period 1928 to 1934. During this period the mean annual rainfall was 34·07 inches. The mean summer rainfall was 27·73 inches, or 81·4 per cent. of the mean annual rainfall; the mean winter fall was 6·34 inches, or 18·6 per cent. of the mean annual fall. Of the 42 winter months covered by these records, a monthly fall of less than half-an-inch is recorded for 19, and for five of these the fall is given as nil. In this area, therefore, periods of heavy rainfall alternate with periods of of intense drought, during which the subsoil is almost completely dried out.

The porous nature of the soil, and in many cases also of the underlying rock, aggravates the sub-surface drought, since rain water is able to percolate to a depth beyond the influence of capillary action, and the drying soil is unable to obtain any supply of water from below. Evidence in favour of deep penetration of percolating water, based upon observations of seepage areas and the poor quality of the plantations of exotic trees, has already been mentioned. Further evidence is the absence of any deep rooted indigenous species, indicating that the plants depend for their supply entirely upon surface moisture.

Thompson (1936) has shown experimentally the small amount of percolation in Transvaal soils resulting from light rains. These results have been confirmed by one of us (Coutts, 1936) for Pietermaritzburg soils. After light showers of rain of up to half an inch, percolation extends only to about five inches. Such rains would serve to supply surface rooted plants, but would have little effect on soil moisture content at lower levels. Thus between periods of high rainfall the sub-soil is subject to a considerable degree of drying out, and develops deep vertical cracks up to an inch wide.

These cracks form an anastomosing system. During severe summer storms, therefore, water is able to collect in them before the general bulk of the soil has absorbed enough water to close them by swelling. On sloping ground a flow of water will occur along the bottoms of the cracks, resulting in the production of channels by corrasion. When the width of any channel is such that it can no longer be closed on wetting the soil, a permanent underground water passage will have developed. Once this process has started it will be accelerated on account of the increased rate of soil drying caused by the more rapid drainage of soil water and by air circulation along the passages.

Soil Shrinkage Experiments.

A few soil samples collected from the eroded area have been submitted to laboratory tests. The characteristic differences

between sandy and clayey soils are too well known to require detailed description, but the data quoted below illustrate the range of differences encountered in the soils concerned in the development of the erosion channels.

Sample A was collected in the sandy horizon (6 to 16 inches below the surface), and Sample B was taken from the very slightly permeable horizon at a depth of three feet. Table 1 shows the pore space of the air dry soil (after being broken up and passed through a 1 mm. sieve); the percentage swelling produced on wetting; the water retained in the saturated soil, as measured by the modified Keen-Raczkowski box method (Coutts, 1930); the results of rough determinations of the force required to crush oven dried pellets; and the time for which the pellet remained half covered by water before it was completely disintegrated on touching gently with a glass rod. It might be added that in the box experiment, the time of wetting of Sample B was much slower than that of Sample A.

TABLE I—Physical Data for Soils A and B.

	Pore Space.	Swelling.	Water Retention	Crushing Force (Arby. Units).	Slaking Time. Mins.
A	44·8	11·0	39·5	3	8
B	48 6	19 6	48 6	4·5	64

These data are in accordance with the deductions from field observations concerning the genesis of the erosion channels. With a sandy horizon lying above a clay layer, the effect of a sudden addition of water is that the water immediately starts to percolate through the sandy soil, while the clay slowly absorbs water and expands, soon becoming impermeable, thus intensifying the corrasive action of the flow through the sand. On subsequent drying and shrinkage cracks are formed, particularly in the clay horizon, and these are in some cases too large to be reclosed by subsequent rewetting, so they form the starting point for further corrasion from their walls, and lead to the gradual widening of the cracks until broad channels are produced.

CONTRIBUTARY FACTORS.

Sub-surface erosion is a natural process of soil transport and erosion, but like all erosion phenomena is likely to be subject to acceleration by any factors which disturb the natural soil and vegetational processes.

Since the area studied has never been under cultivation, this need not be considered as a contributary factor in the present case.

Some years ago, a road was constructed on the ridge above the area, as is shown in Fig. 1. The chief drainage from this road, however, is spilled on to the opposite slope on which there are fewer sub-surface channels, and road drainage has not been

a factor of any importance in increasing erosion in the area studied.

No definite information is available with regard to the history of veld management since the farm was occupied. Contour and other paths made by stock are in evidence, but no serious surface erosion has resulted. Veld burning during winter is practised, and annual or biennial burning may have been continuous since European occupation. The sub-surface channels, cones and fans are apparently fairly old, and it is now impossible to correlate them with excessive grass burning or overstocking.

Remedial Measures.

The following remedial measures are suggested:

1. As dense a grass cover as is possible should be maintained on the steeper slopes of the ridges, thus reducing the run off on to soils liable to sub-surface erosion.

2. On areas subject to sub-surface erosion grazing should be regulated so as to maintain a good grass cover, in order to prevent excessive loss of moisture by evaporation.

3. It has been pointed out that in this area surface erosion is a slower process than sub-surface erosion, and in all cases in which water is forced to the surface reclamation has been more rapid than erosion. It is suggested, therefore, that the channels should be closed at intervals by breaking in the roofs and shovelling in the surrounding top soil. In this way a number of small dams would be formed, which would serve to retain water and cause deposition of some of the material eroded from the channels. Any overflow from these dams would be spread out on the surface and held up by grasses. The increased soil moisture produced by the dams would have the effect of inhibiting the development of soil cracks.

Summary.

A new type of sub-surface erosion due to the corrasive action of underground water is described and analysed. The erosion is due to the production of an anastomosing system of vertical cracks in the drying subsoil, thus permitting the formation of underground water channels during heavy rain. The life history of the underground channels is traced and several remedial measures are suggested.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV*, *pp. 244-245*, *December, 1938.*

PRELIMINARY REPORT ON THE NITROGEN PROBLEM IN PASTURE SOILS OF THE NATAL SOUR VELD

BY

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Read 5 July, 1938.

ABSTRACT

The decline in production of improved pasture land (sown to grass only) is associated with a decrease in the amount of available nitrogen in the soil as evidenced by marked response to applications of nitrogenous fertilisers and by chemical analyses. If yield and composition are considered, an acre of good Paspalum dilatatum grassland is capable of removing annually from the soil nitrogen equivalent to 800 lbs. of ammonium sulphate per acre per annum.

INOCULATED LEGUMES IN PASTURE.

The available nitrogen figures for virgin veld seldom exceed 10 parts per million, whereas figures for high producing grass and clover pastures often exceed a figure of 30 parts per million. This indicates that the introduction of inoculated legumes in pasture land has a most favourable effect on the amount of available nitrogen in the soil. The value of clover as an aid to nitrogen fixation is dependent on the strain of bacteria in the clover nodules. Some strain investigational work now in progress at Cedara is briefly described.

UPTAKE OF AMMONIUM SULPHATE.

In an experiment on Paspalum pasture, 800 lbs. of ammonium sulphate per acre was applied. The rate of uptake of ammonium sulphate by the grass was studied by means of available nitrogen analyses of samples drawn from the replicate plots at weekly intervals. The data obtained indicate that the rate of uptake is extremely rapid, dropping from 82 to 8 parts of NH_3.N + NO_3.N per million over a period of some six weeks. On the basis of percentage nitrogen in yield, the actual recovery of nitrogen in 1 cut of Paspalum was found to be about 65 per cent.

EFFECT OF DEGREE OF NODULATION ON CLOVER GROWTH AND COMPOSITION.

The tops and roots of the indigenous Trifolium africanum exhibiting 3 degrees of nodulation were collected and analysed. The results obtained indicate that high total nitrogen and calcium oxide figures are associated with the better nodulated plants.

CLOVER PASTURES IN THE NATAL SOUR VELD.

Factors controlling successful mixed pasture establishment are briefly discussed. Sufficient moisture, inoculation of clover seed with an effective strain, adequate phosphate supply, thorough pre-preparation of soil, and good management ensure successful establishment

ACKNOWLEDGMENT.

An acknowledgement is made to Dr. E. R. Orchard (Pretoria) for the basis of the microbiological pasture research at Cedara.

LEAF SAP OSMOTIC PRESSURES OF SOME NATAL PLANTS

BY

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Read 8 July, 1938.

ABSTRACT.

SUMMARY.

Results were given of cryoscopic determinations of osmotic pressures of expressed leaf sap of some Natal plants. The range for trees is from 19·6 to 41·2 atmospheres; for herbs from 3·6 to 16 0 atmospheres; and for succulents from 2·8 to 15 4 atmospheres.

VIABLE SEED CONTENT OF VELD SOILS

BY

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Read 7 July, 1938

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EFFECT OF FERTILISER TREATMENT ON TRANSVAAL HIGHVELD

BY

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Read 7 July, 1938.

ABSTRACT.

Data are presented on the effect of various combinations of fertiliser treatments on the yield and chemical composition of the herbage of Transvaal Highveld and on the chemical composition of some important individual grasses of this type of veld.

Fertiliser combinations supplying the elements nitrogen, phosphorus and potassium increased the phosphorus and nitrogen content of the total herbage as well as of individual species.

PNK treatment also greatly increased the yield of the herbage and consequently the total uptake of phosphorus and nitrogen.

Nitrogen in the form of sulphate of ammonia had the same effect as nitrogen in the form of nitrate of soda.

In spite of a considerable increase of the yield and of the total uptake of nitrogen and phosphorus by the PNK treatments, the actual amounts of phosphorus and nitrogen recovered in the herbage of these treatments per unit area were very small as compared with those given as fertilisers.

PK treatment (without nitrogen) did not affect the yield of the herbage. It increased the phosphorus content, but depressed the nitrogen content and uptake of the herbage.

At the end of the growing season *Trachypogon plumosus* possessed a considerably higher phosphorus and nitrogen content than the total herbage.

The results also indicate that different species respond in different ways to the fertiliser treatments applied.

EXPERIMENT I.

TABLE I—Physical and Chemical Properties of Surface Soil.

Percentages of Oven Dry Fine Soil.				
	Particle Size (mm.).		Maximum Water Retaining Capacity	35·6
Sand	0·05 —1·0	79·4	Loss on Ignition	3 0
Silt	0·005—0·05	12·0	Nitrogen	0·066
Clay	<0·005	8·6	Phosphoric Oxide ...	0·019
Total Colloids .	<0·008	10·4	Potash	0·046

Remarks.—The surface soil of the area (Frankenwald Research Station) is an acid grey-brown loamy sand on a subsoil of decomposed granite, interspersed with frequent outcrops of quartz and ouklip. For the mechanical analysis the Boyoucos Hydrometer Method was used (Boyoucos, 1930); potash and phosphoric oxide were determined in the hot 10 per cent. hydrochloric acid extract and nitrogen by the ordinary Kjeldahl method.

TABLE II—Chemical Composition of Herbage.
Percentages of Dry Matter.

	N			P_2O		
Treatment.	O	PNK	PN_3K	O	PNK	PN_3K
Trachypogon plumosus	1·10	1·41	1·30	0·18	0·31	0·29
Tristachya hispida ...	1·06	1·21	1·27	0·19	0·31	0·32
Digitaria trichol. ...	0·89	1·02	1·13	0·17	0·31	0·26
Total Herbage ...	0·88	1·32	1·27	0·15	0·31	0·27

Remarks.—Fertiliser treatments: O = no fertiliser, P = 400 lb. of a mixture of equal quantities of super-and rock phosphate per morgen, K = 80 lb. of muriate of potash per morgen. N = 200 lb. of sulphate of ammonia per morgen. Since 1933, when the experiment was started, these fertiliser treatments have been applied annually in the beginning of the growing season, apart from the additional applications of nitrogen in the PN_3K treatment which were given in two further dressings of 200 lb. of sulphate of ammonia per morgen at convenient intervals during the season (in 1935/36 on 15/2/1936 and 16/3/1936). The herbage samples were taken on 30th January, 1936; at this date *Digitaria trich.* was in full flower, *Tristachya hisp.* had developed only few inflorescences and *Trachypogon pl.* was not yet in bloom. The experiment has been described in detail by Hall, Meredith and Murray (1937) who determined yields and chemical composition of the total herbage of these camps in the same year. The values for the total herbage in Table II are those given by Hall, Meredith, and Murray for the sample collected on 11th February, 1936.

EXPERIMENT II.

Laid out by the writer at Frankenwald in October, 1937, on undisturbed *Trachypogon* veld and consisting of plots of 100 square yard area, each receiving one of the following treatments: O – PK – PN_3K (nitrogen in the form of sulphate of ammonia) – PN_3K (nitrogen in the form of nitrate of soda). The quantities of nutrients supplied are the same as in Experiment I. Each treatment is replicated four times.

The soil is very similar to that of Experiment 1; a representative soil sample was taken before the fertilisers were applied.

TABLE III—Physical and Chemical Properties of Surface Soil.

Percentages of Oven Dry Fine Soil.			
Loss on Ignition	3·8	Nitrogen	0·102
Maximum Water Retaining Capacity	32·8	Phosphoric Oxide ...	0·019
		Potash	0·057

At the end of the growing season (2-4/5/1938) the total herbage of all plots was harvested and a sample of 100 *Trachypogon* tussocks was separately collected in each plot. Table IV gives the average dry weights of herbage together with their corresponding standard errors. All figures for total herbage (yield and chemical composition, Table IV and V) include the corresponding amounts for the *Trachypogon* plants sampled separately.

TABLE IV—Yields of Herbage.

Average Dry Weights of Herbage in KG.

Treatment.		Total Herbage of 100 sq. yd. Area.		100 *Trachypogon* Tussocks.	
I	O	15·40	±1·38	1·13	±0·10
II	PK	13·93	±0·91	0·96	±0·14
III	PK + sulphate of ammonia	24·34	±1·71	1·24	±0·10
IV	PK + nitrate of soda ...	24·69	±1·66	1·33	±0·14
		Differences.			
II – I	... ...	– 1·47	±1·65	– 0·17	±0·17
III – I	.. ..	+8·94	±2·20	+0·11	±0·14
IV – I	.. ..	+9·29	±2·16	+0·20	±0·17
IV – III	... ...	+0·35	±2·39	+0·09	±0·17

Remarks.—The yield of the *total herbage* was greatly increased by the two fertiliser treatments which included nitrogen, whereas the PK treatment brought about no significant change; sulphate of ammonia produced the same yield as nitrate of soda. No significant differences, however, are shown between the yields of the *Trachypogon* samples. It must, therefore, be concluded that the fertiliser treatment has increased the yield of the total herbage mainly by increasing the proportion of species other than *Trachypogon pl.* For clearing purposes the whole plot had been burnt before the experiment was laid out and it was noticed in the following season that on the burnt area—irrespective of fertiliser treatment—*Trachypogon pl.* formed only very few flower-

ing stems. Possibly, the small response of *Trachypogon* to the fertiliser treatment is connected with the influence of the previous burn.

TABLE V—Chemical Composition of Herbage.

Total Herbage.

	Treatment.	%N	%P_2O_5	g.N Taken up per Plot	g.P_2O_5 Taken up per Plot
I	0	0·49	0·09	74·7	14·5
II	PK	0·43	0·15	60·1	20·3
III	PK + sulphate of ammonia	0·52	0·11	126·5	23·3
IV	PK + nitrate of soda	0·53	0·11	132·0	27·7

Trachypogon plumosus.

	Treatment.	%N	%P_2O_5	g.N In 100 Tussocks	g.P_2O_5 In 100 Tussocks
I	0	0·63	0·12	7·06	1·40
II	PK	0·64	0·19	6·17	1·88
III	PK + sulphate of ammonia	0·82	0·17	10·22	2·05
IV	PK + nitrate of soda	0·83	0·17	10·96	2·20

Remarks.—Both PNK treatments have distinctly increased the nitrogen and phosphorus content of total herbage as well as of *Trachypogon* plants. But in contrast to the changes in the yields, the changes in chemical composition are far more distinct in *Trachypogon pl.* than in the total herbage—showing again that *Trachypogon pl.* has responded to the fertiliser treatment in a manner quite different from other species with which it is associated in the total herbage. In *Trachypogon pl.* it is the quality, whereas in the total herbage it is rather the quantity which has been improved. The chemical composition of *Trachypogon pl.* compares in all cases very favourably with that of the total herbage. When the additional uptake of nitrogen and phosphoric oxide by the well fertilised (PNK) plants is compared with the actual amounts of these nutrients supplied as fertilisers, it is shown that only a surprisingly small proportion of the nutrients supplied has been recovered in the herbage. Thus, the total herbage of treatment IV, where the absorption was highest, contained 13·2 g P_2O_5 and 57·3 g N per plot in excess of the control, but 432 g total P_2O_5 (including 180 g water soluble P_2O_5) and 575 g N per plot had been supplied in both PNK treatments.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 250-258, December, 1938.*

A CONTRIBUTION TO THE LEAF ANATOMY OF NATAL GRASSES: *TRICHOLAENA* Schrad.

BY

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With 5 Text Figures.

Read 7 July, 1938.

INTRODUCTION.

In the "Flora Capensis" (vol. VII), Stapf described six South African species of the genus *Tricholaena*, three of which are recorded for Natal (Bews, 1918). *T. repens* (Willd.) Hitchc. (Natal Red Top Grass, or Natal Grass) is generally a semi-annual and a widespread ruderal which is dominant in about the second or third year after secondary succession commences in waste land. In its perennial form it colonises stony hillsides, and is widely distributed over drier regions from west to east (Bews, 1918). *T. setifolia* Stapf grows in compact tufts and is an important pioneer in the early stages of grassland succession. *T. glabra* Stapf is rare, and as no material was available, it has not been possible to investigate its leaf anatomy.

METHODS.

Fresh mature vegetative shoots of *T. repens* and *T. setifolia* were preserved in 50 per cent. alcohol to remove the chlorophyll. As anatomy varies with the leaves selected (Burr and Turner, 1933) only mature leaves of vegetative shoots should be used and freehand sections should be cut one third of the distance between ligule and apex. Strassburger's (1924) glycerine jelly method, using safranin as a stain, gives most satisfactory permanent mounts. The shoot should be sectioned just below the outermost sheath, and again near the base to ascertain whether the sheath is split throughout its length.

A uniform method of illustrating the different tissues has been adopted, and this is indicated in the legend given below.

THE SHOOT.

Vegetative shoots consist of very short stems on which the leaves are crowded together and protected by the outer sheaths. Shoots may be either round, oval, or compressed, and young leaf blades are either rolled or folded. Burr and Turner (1933)

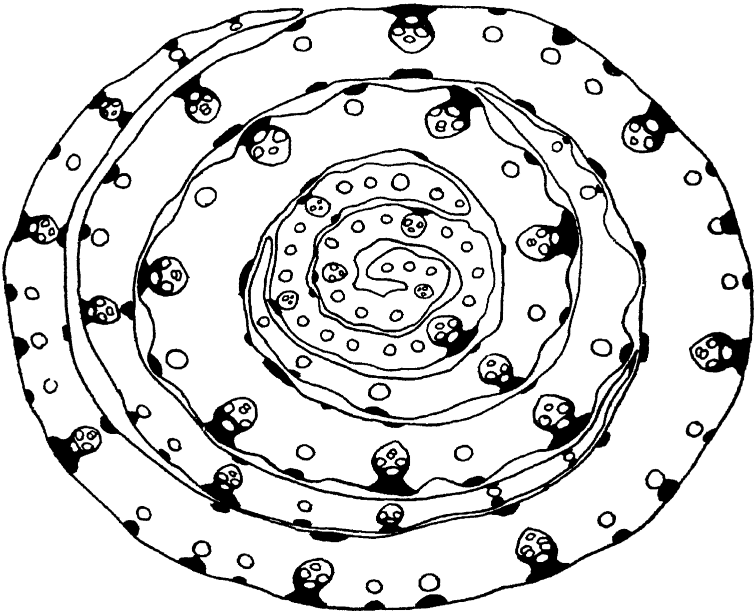

Fig. 1.—T.S. Shoot, *Tricholaena repens* (Willd.) Hitchc.

1 m.m.

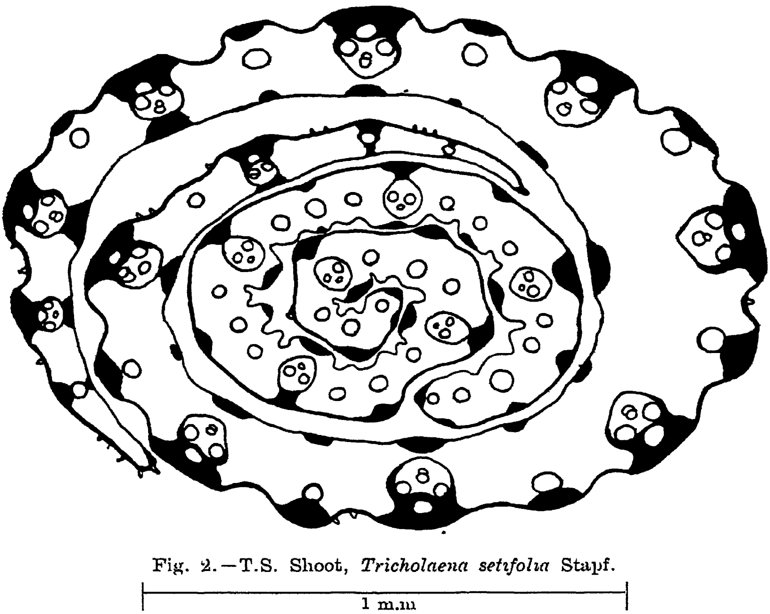

Fig. 2.—T.S. Shoot, *Tricholaena setifolia* Stapf.

1 m.m

have stressed the suitability of this character for use in an anatomical key, and it has the advantage of being determined easily with the aid of a hand lens.

In the two species the young leaf blades are rolled in the bud. In *T. repens* (fig. 1) the shoot is round, and in *T. setifolia* (fig. 2) slightly compressed. The sheaths are split throughout their length, overlapping of the margins being evident. The sheath of *T. setifolia* is ribbed, slightly keeled, and villous particularly in the basal region. Both species have bundles of the first and third order adjacent to the lower epidermis, with chlorenchyma between the bundles. A stereome strand is present above and below all first order bundles, but is not confined to them. The study of these species and other grasses indicates that a satisfactory diagnostic key based on the anatomy of the sheath alone would be difficult to establish.

Anatomy of the Leaf.

The Epidermis. (Fig. 3).

The epidermis shows a complex structure, and this is characteristic of other grasses, eg. *Oryza sativa L.* (Arber, 1934) and *Chloris spp.* (Fisher, 1939). When examined in surface view two alternating bands of cells can be distinguished. The cells adjacent to the first, to the second, and also usually to the third order bundles are much smaller and often shorter than those between the nerves.

Cells between the nerves. In the upper epidermis this region consists of motor cells interrupted by stomata. In the lower epidermis of both species this region is occupied by cells which are ripple walled, rectangular in shape, and interrupted at intervals by stomata and solitary or pairs of short cells. Solitary short cells are suberised, and when a pair is present one is suberised and the other is silicified. Flanking the nerves, and sometimes midway between the bundles, the suberised cells may be replaced by hairs.

The hairs are of three kinds—rather long, thin walled hairs with truncate apices, short bulbous silicified hairs with pointed apices, and long, thick walled terete hairs. At an early stage of development the hairs with truncate apices consist of two cells, but the terminal cell shrivels gradually and finally drops off (fig. 3b). All three kinds of hairs occur in *T. setifolia* particularly in the upper epidermis, but *T. repens* lacks the terete hairs.

In surface view motor cells have smooth, thin walls, and are rectangular in shape in *T. repens* (fig. 3a) and pentagonal in *T. setifolia*. In transverse section, pear shaped motor cells flank the midrib, and they also occur in groups of three to five cells between the third order bundles. They are flush with the ordinary epidermal cells into which they grade gradually. In figs. 4 and 5 it will be seen that the motor cells on either side of

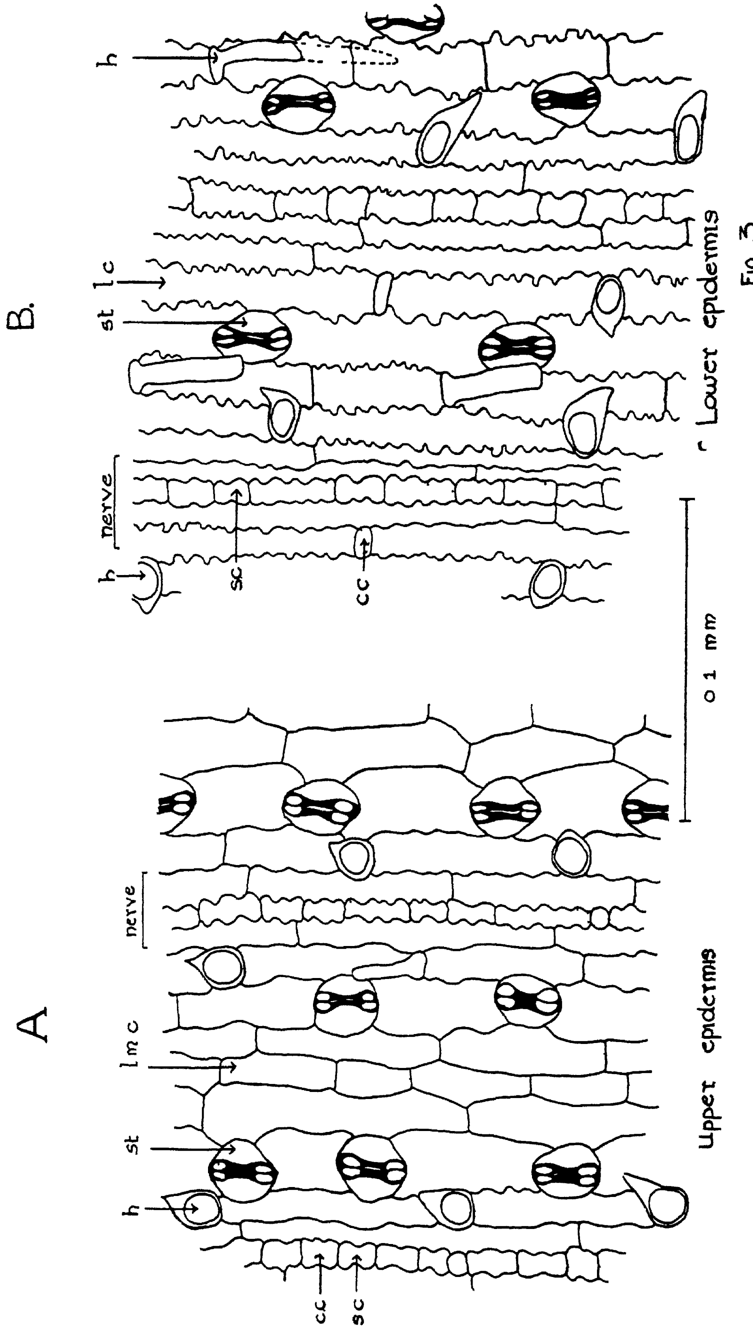

Fig 3
TRICHOLAENA REPENS (willd) Hitchc.

a third order bundle often link up forming a continuous band of about eight cells. In *T. setifolia* the motor cells may be interrupted by silicified hairs (fig. 5).

Stomata occur on both surfaces of *T. repens* in approximately equal numbers. In *T. setifolia* they are more numerous in the upper epidermis. In transverse section it will be seen that the stomata are almost flush with the surface of the epidermis. Figs. 4 and 5 indicate that the accessory cells of both species have a peculiar shape, being notched in the central region abutting the guard cells.

Cells adjacent to the nerves. In surface view (fig. 3), the cells adjacent to the vascular bundles consist of files of short elements alternating with longitudinal rows of long cells, all of which are ripple walled and not interrupted by short cells. The smaller nerves show a single file of short elements with suberised and silicified cells alternating. Where two adjacent groups of motor cells link up with one another the files of short cells are absent, and stomata may occur opposite third order bundles (fig. 4).

Vascular Bundles.—The structure of first, second, and third order bundles (figs. 4 and 5) is too uniform to be useful in the identification of grasses, but in the Natal species of *Tricholaena* the ratio of first to third order bundles is a reliable guide. In *T. repens* 5, 6, or 7 third order bundles occur between two adjacent first order bundles. In *T. setifolia*, where the blade is narrower, the first order bundles are closer together, separated by three third order bundles, though the central one of these may be replaced by a second order bundle.

The Midrib.—A conspicuous midrib is not characteristic. There is no colourless parenchyma in the lateral part of the blade, but several rows of colourless cells are developed adjacent to the midvein in *T. setifolia*. This is also present in some leaves of *T. repens*, but is absent in others where the midrib consists of the midvein only (fig. 4).

The Mechanical Tissue or Stereome.—*T. repens* (fig. 4) has very little sclerenchyma, while *T. setifolia* (fig. 5) contains a good deal of mechanical tissue. This is confined to the region above and below the bundles, being conspicuously developed adjacent to first order bundles, a few of which are girdered in *T. setifolia*, but there is no evidence of girdering in *T. repens*. In *T. setifolia* stereome strands are often absent in the region of third order bundles, but they are generally weakly developed in *T. repens*. The distribution and quantity of mechanical tissue is a diagnostic character of importance, and its arrangement in the midrib and margin should be noted. In both species it occurs in the keel, opposite the midvein where it interrupts the motor cells, but it is not conspicuously developed at the margin.

Description of Species.

Only the more important anatomical features are given.

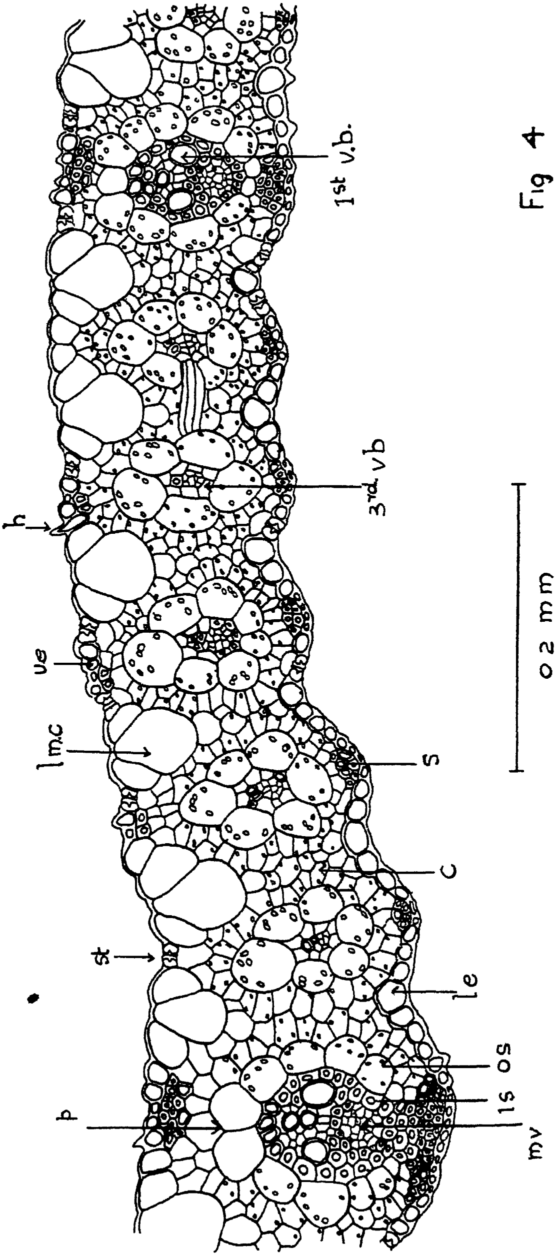

Fig 4
T S LEAF
TRICHOLAENA REPENS (willd.) Hitchc

Tricholaena repens (Willd.) Hitchc.—Leaf thin, upper surface flat, lower slightly undulating; blade with a small keel. Epidermis with motor cells flanking the midrib, and developed in the lateral part of the blade between the nerves, generally in groups of three cells, which may link up over a third order bundle, occupying one third the depth of the leaf; stomata on both surfaces, generally between the nerves; epidermal cells with short bulbous hairs and thin walled hairs with truncate apices, flanking nerves. 9 or 11 first order bundles, inner bundle sheath of lignified elements, outer sheath of 10 to 12 large parenchyma cells with chloroplasts, sometimes interrupted by a stereome strand below; 5, 6, or 7 third order bundles between those of the first order, bundle sheath single, about 6 parenchyma cells with chloroplasts, not interrupted by a stereome strand. Midrib with or without colourless parenchyma. Margin without special features. Chlorenchyma of regular cells with chloroplasts. Stereome poorly developed, but present in the keel, opposite the midvein, and adjacent to the bundles which are not girdered, absent in some third order bundles.

Tricholaena setifolia Stapf.—Leaf fairly thin, both surfaces slightly undulating, blade with a round keel. Epidermis with motor cells flanking the midrib in groups of 8 to 10 cells, and also in the lateral part of the blade in large or small groups, not confined to the region between the bundles, occupying one third the depth of the leaf; stomata on both surfaces, generally between the bundles; epidermal cells with hairs of three kinds generally flanking nerves, hairs more numerous on the upper surfaces; lower epidermal cells with a thick cuticle. 7 or 9 first order bundles, inner bundle sheath of lignified elements, outer sheath of 12 to 14 parenchyma cells with chloroplasts, interrupted by a stereome strand below; second order bundles variable in number, when present occurring midway between those of the first order, inner bundle sheath lignified, outer of 8 to 10 parenchyma cells not interrupted by a stereome strand; 2 third order bundles (or 3 if second order bundle absent) between those of the first order, bundle sheath single, 5 or 6 parenchyma cells with chloroplasts, often with no stereome strand. Midrib with several layers of colourless parenchyma. Margin without special features. Chlorenchyma of regular cells with chloroplasts. Stereome present in the keel, opposite the midvein, and well developed adjacent to first and second order bundles which are usually not girdered, generally absent adjacent to third order bundles.

SUMMARY.

1. An account is given of the leaf anatomy of two Natal species of *Tricholaena*, illustrated by 5 text-figures.

2. The structure of the epidermis is complex. Adjacent to the nerves, files of short elements, consisting of alternating suberised and silicified cells, occur. In the region between the nerves long ripple walled cells are present in the lower epidermis, and

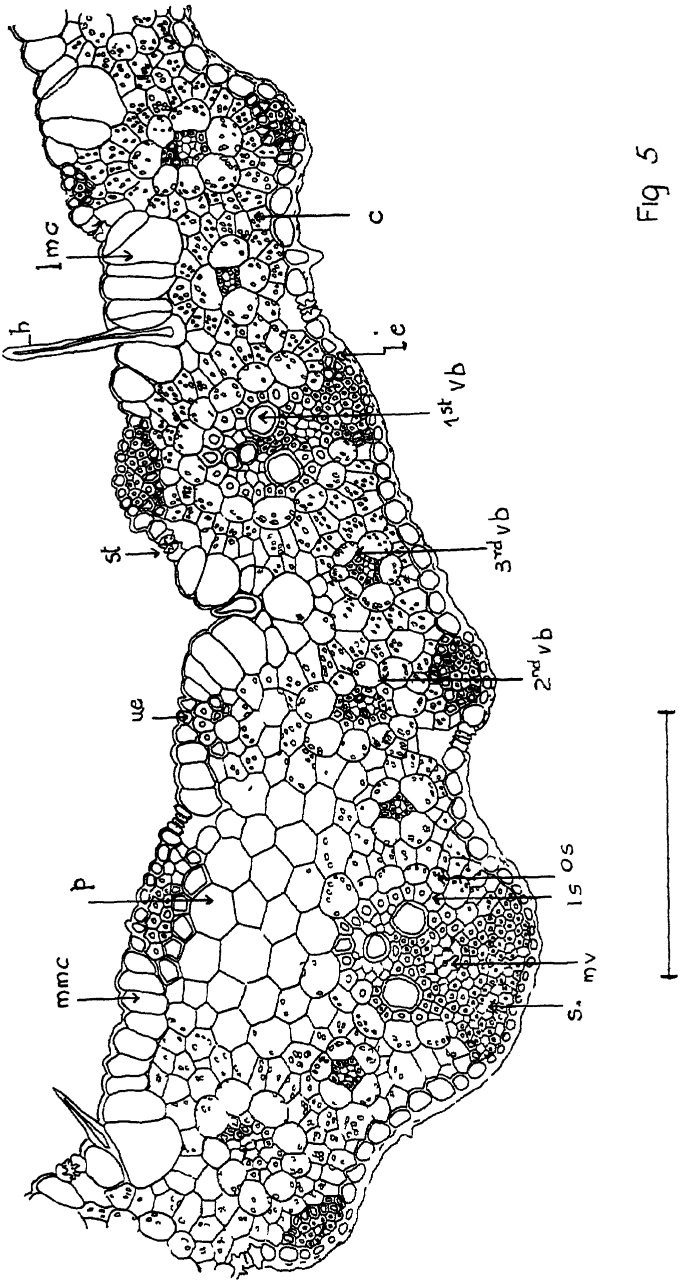

Fig 5
T S Leaf
TRICHOLAENA SETIFOLIA Stapf

these may be interrupted by short cells and by stomata. In the upper epidermis this region is occupied by motor cells and stomata. Short suberised cells may be replaced by hairs.

3. The vascular bundles are classified into first, second and third order bundles. The second order bundles are rather erratic in occurrence, but the ratio of first to third order bundles is a useful guide in distinguishing between *T. repens* and *T. setifolia*.

4. The margin shows no special features, and is not thickened nor more strongly lignified than the rest of the blade.

5. The chlorenchyma consists of regular cells, and there is no colourless parenchyma in the lateral part of the blade.

6. A well developed stereome strand is present in the keel, and above the midvein in both species. Stereome strands occur in association with the vascular bundles, but girdering is not a feature.

7. The anatomical characters of each species are described.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 259-262, December, 1938.*

THE SOUTH AFRICAN SPECIES OF *CTENIUM* PANZ.

BY

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With 2 Text Figures.

Read 7 July, 1938.

Of this genus about 12 species are known. These are natives of North and South America and Africa. The six African species, as given by Pilger (1924), are mainly confined to the tropics. In South Africa it is represented by a single species, which extends from the Transvaal through Natal (?) into the Transkei districts.

HISTORY AND NOMENCLATURE.

The type species is *Chloris monostachya* Michx. In 1810 Desvaux (Nouv. Bull. Soc. Philom, Paris, 2: 189) described his genus *Campulosus* to which he refers two species, viz., *C. gracilior* Desv. and *C. hirsutus* Desv. The former is based on *Chloris monostachya* Michx., which, according to Hitchcock (1936), is Wood's *Ctenium aromaticum* (Walt.) from North America. *C. hirsutus* Desv. is based on *Chloris falcata* Swartz, which has since been referred to the genus *Harpechloa* Kunth. In 1813 Panzer (Denkschr. Baier. Akad. Wiss. Munchen 4: 288, pl. 13) described his genus *Ctenium*, to which he refers a single species, viz., *Ctenium carolinianum*, which Michaux (Fl. Bor. Amer. 1, 1803) has previously described as *Chloris monostachya*. Under the International Rules of nomenclature Panzer's generic name, *Ctenium* has been conserved for this genus, with *Chloris monostachya* as the type.

In 1816 Elliot (Bot. S.C. and Ga. 1: 176) described the genus *Monocera* to which he referred a single species based on *Aegilops aromatica* Walt., which, according to Hitchcock (1936), is now *Ctenium aromaticum* (Walt.) Wood. Later on Rafinesque (Amer. Month. Mag. 4: 190) suggested the name *Monathera* for Elliot's generic name, as he found that there is already a genus of shell of the same name.

DESCRIPTIONS.

Densely tufted perennial, rarely annual. *Spikes* terminal, 1 – 3, digitate; spikelets 3 – 4-flowered, sessile, unilateral and biseriate, pectinate, awned. *Glumes* unequal; lower persistent, keeled, 1-nerved; upper firm, 2 – 3-nerved, rigidly awned from the middle. *Lemmas* thin, 3-nerved, ciliate along the nerves or the

uppermost glabrous, awned from below the tip. *Pale* 2-nerved. *Stamens* 3, or 2 in male flowers. *Grain* free, enclosed by its lemma and pale.

1. *C. concinnum* Nees in Fl. Afr. Austr. 237 (Figs. 1 and 2).

Perennial; culms up to 2 feet long, 2-noded; leaves mostly basal, up to 1 foot long, linear, 1—2 mm. wide; spikelets 6—7 mm. long; lower glume about 3 mm. long, with a scabrid keel; upper glume about 6 mm. long, awned with an obliquely erect awn; lemmas about 3 mm. long; lowest lemma sterile; second lemma male, with a rudimentary pale and two perfect or imperfect anthers; third and fourth lemma bisexual.

Leaf anatomy.—Keel absent and midrib ill-defined. Abaxial surface undulating, with occasional asperities. Adaxial surface ribbed, with the ribs more or less equal and bearing asperities, with narrow furrows between ribs. Mechanical tissue above and below bundles. Parenchyma absent opposite midrib. Bundles with double bundle-sheath; inner bundle-sheath one-layered except in main bundle where it is double-layered; outer bundle-sheath consisting of brick-shaped cells containing chloroplasts, interrupted by abaxial stereome strands in first order bundles, horse-shoe-shaped in second order bundles, with a circular space separating the adaxial ends of bundle-sheath in first order bundles. Chlorophyll tissue in two layers of small radiating cells round bundles, separated by strands of clear cells extending from the motor-cells to the abaxial epidermis. Motor-cells present at base of ribs, consisting of a large more or less M-shaped central cell and 2—3 auxillary cells on either side. Abaxial epidermis consisting of rows of cells composed of long cells alternating with groups of two short cells of which one is a cutinised cell and the other a silicified cell, with the silicified cell often bearing asperities; in region of stomata consisting of rows of long cells, or the rows composed of long cells alternating with groups of 1—2 short cells; stomata in two rows. Margins without mechanical tissue.

Transvaal.—Barberton, *Liebenberg* 2500 (*Nat. Herb. Pret.*); Thorncroft 8 (*Nat. Herb. Pret.*); Duivelskantoor, *Pole-Evans* 1010 (*Nat. Herb. Pret.*); Carolina, Leeuwpoort, *Burtt-Davy* (*Nat. Herb. Pret.* 2959 and 7331); Ermelo, Billy's Vlei, *Burtt-Davy* (*Nat. Herb. Pret.* 6132 and 9226); Lake Chrissie, *Hamilton* (*Nat. Herb. Pret.* 4332); Lydenburg, *Burtt-Davy* (*Nat. Herb. Pret.* 1340); Middelburg, Panplaas near Pan Station, *Burtt-Davy* (*Nat. Herb. Pret.* 13289 and 13320); Pretoria, *MacDonald* (*Nat. Herb. Pret.* 5480):

Cape Province.—Pondoland, between St. John's River and Umtsikaba River, *Drège* (*Kew Herb.*); *Mogg* 333 (*N.U.C. Herb.*).

We have not seen all the specimens cited by Stapf in Dyer's "Flora Capensis," Vol. VII, 639. We wish to thank the Chief, Division of Plant Industry, Pretoria, for kindly placing the material in the National Herbarium at our disposal. The other South African herbaria have no material of this genus. We are

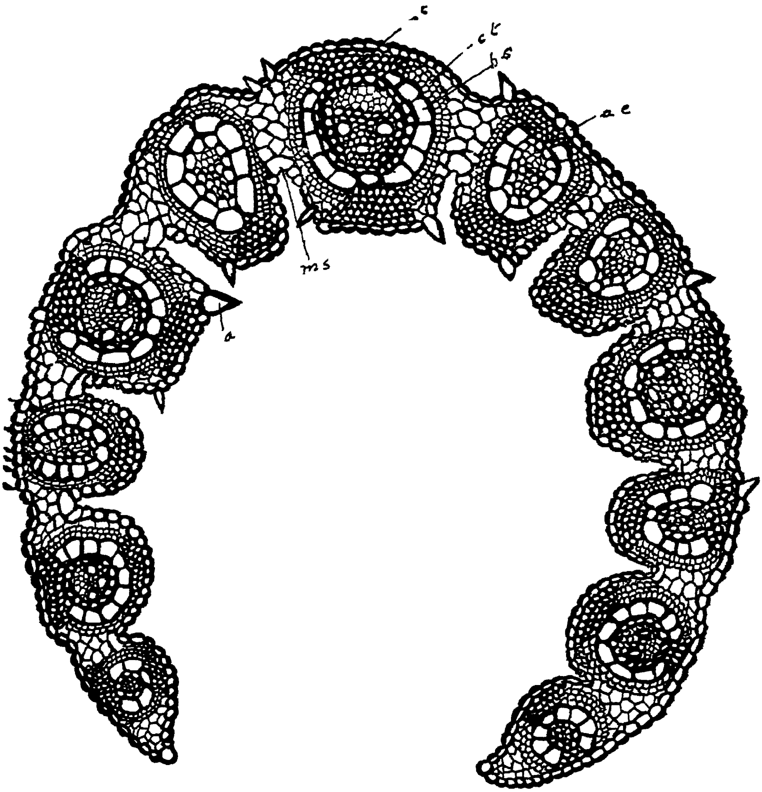

Fig. 1.—Transverse section of leaf. × 2000. a. – asperities; m.s. – motor cells; m.t. – mechanical tissue; c.t. – chlorophyll tissue; b.s. – bundle-sheath; a.e. – abaxial epidermis.

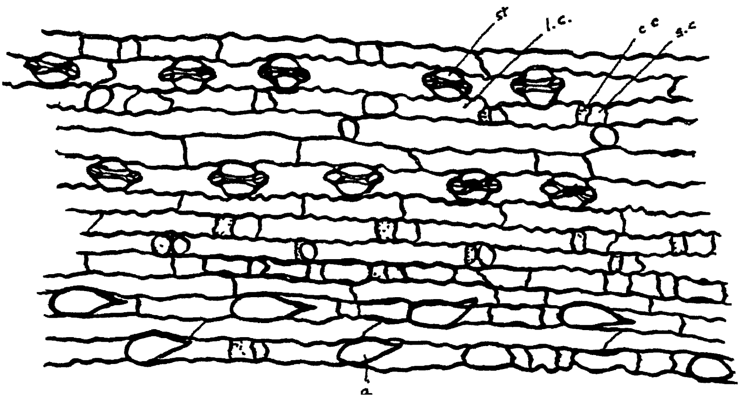

Fig. 2.—Surface view of abaxial epidermis of leaf. × 2000. st. – stoma; l. c. – long cell; c.c. – cutinised cell; s.c. – short cell; a. – asprities.

furthermore indebted to the Director, Royal Botanic Gardens. Kew, for supplying us with a leaf of the type specimen collected by Drège.

SUMMARY.

1. The history and nomenclature of *Ctenium* Panz. is given.

2. It was found that this genus is represented in South Africa by a single species.

3. The leaf anatomy is described and the distribution of the species in South Africa is given.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 263-273, December, 1938.*

A COMPARISON OF VARIOUS FIELD ECOLOGICAL LIGHT MEASURING INSTRUMENTS, AND A FURTHER CONTRIBUTION TO OUR KNOWLEDGE OF THE EDER HECHT PHOTOMETER AND THE LIVINGSTON RADIO ATMOMETER

BY

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Read 5 July 1938.

INTRODUCTION

This paper is a continuation of the paper published in the South African Journal of Science, March, 1937. It is essentially a discussion of various simple light measuring instruments from the point of view of their relative efficiency, and use, to the field ecologist.

The Eder Hecht photometer, the Livingston Radio Atmometer, the Weston Photronic cell and the Solar Radiation Thermometer are all discussed.

EDER HECHT GRAUKEIL PHOTOMETER.

The Eder Hecht Photometer is a photochemical method of measuring light, measuring only the short wave lengths of light. The photometer is used in Europe, and in several South African Pasture Research and Forestry Stations.

Construction.—The photometer consists essentially of a wedge of opalescent diffusing glass, and behind this is a blackened scale and a strip of silver chloride, photographic paper.

There are three types of photometer supplied by the Dorno Physikalisch Meteorologisches Observatorium, Davos. They have the following wedge constants:—

0·305. This model is used if daily integrations of light are required. It can be used for shorter periods. On clear, South African, summer days, readings have been obtained after 40 minutes exposure.

0·188. This is a very short period photometer. In strong, direct light, 15 minutes is the period of exposure. It is a useful instrument if low light intensities are to be measured.

0·401 This model can be exposed in South Africa for three or four days. In Switzerland it can be exposed for seven days.

Theory.—A method of measuring light based on the change of colour in silver salts, is likely to introduce errors that are impossible to prevent or correct, as there is no satisfactory formula that adequately expresses the unknown law of the reaction of light on silver salts.

A second source of error lies in the fact that the Brom silver chloride gelatine paper is only sensitive to the short waves of light.

The paper has a maximum sensitivity at about λ 450, a low sensitivity at λ 520, and is not affected by wave lengths longer than λ 570.

Elimination of the Fixing Process.—The photographic strips are fixed before they are read. The scale values are then converted into Relative Light Intensity sums, by referring to a table supplied by Davos.

The strips are fixed in groups of thirty. The solution for one group of strips is made by diluting 100 grams of Agfa Neutral Toning and Fixing Salts in ½ litre of distilled water. This solution must be allowed to stand for at least two days, to allow the insoluble particles to settle. The strips are fixed at a temperature of 18°C. for 8 minutes, in a yellow light. The strips are then washed in running water for 1 hour.

If these instructions are not very carefully carried out, the Davos Observatory (1934) point out that errors of ± 50 per cent. can be introduced. The possibility of errors being introduced in the fixing process, can readily be gauged by the fact that an 18 per cent. error was made by soaking the strips in distilled water for 30 seconds before placing them in the solution.

To eliminate the fixing process, strips were read before they were fixed and afterwards, to find the difference in the scale values. The fixed strips always gave lower scale values than the strips read before they were fixed. Considering all the readings taken during 1935 and 1936, the following reduction factors were found.

Wedge Constant of Photometer.	Reduction Factor.
0·305	– 12
0·188	– 23

Unfortunately, there is insufficeint data available for a a reduction factor to be found for the very long period photometer, with wedge constant 0·401.

To use these reduction factors, the strips are read as soon as they are taken from the instrument. The factor is then subtracted from the scale reading, and the new value is converted into a Relative Light Intensity sum, by using the table supplied with the instrument.

Practical Considerations.—As a field instrument, the photometer is a good one. It is small, light and easily managed in the

field. It is cheap enough for several to be purchased by the field ecologist. Care must be taken to see that water does not get in between the glass wedge and the metal case.

The Observatory, Davos, suggest the possibility of errors incurred by storing strips. Results show, that storing strips does not significantly affect the reduction of scale units during fixing, and also that these errors are insignificant compared with the errors introduced by the fixing process.

Effect of Temperature on the Photographic Strip.—To test the effect of temperature on the Eder Hecht strip, two photometers were exposed simultaneously. The temperature of one instrument was higher than that to which ordinary atmospheric conditions would raise it. Using Fisher's (1930) method of finding the significance of small means, the results are recorded below.

TABLE I.

To Show the Effect of Heat on Fixed and Non-fixed Eder Hecht Strips.

Group	Control Means	Heat Means	Difference of Means	Significance	% Error
1. Non-fixed ...	47·09 ...	63·89 ...	16·80 ...	Significant ...	35·7
Fixed ...	13·66 ...	13·32 ...	0·34 ...	Not Significant ...	—
2. Non-fixed ...	56·84 ...	78·91 ...	22·07 ...	Significant ...	38·8
Fixed ...	27·05 ..	27·87 ...	0·83 ..	Not Significant ...	—

This shows that heat has a significant effect on strips before they are fixed, but no effect after they have been fixed.

Effect of Moisture on the Photographic Strip.—Moisture affects the colour of the exposed strip. Dry strips are dark purple, while moist strips are a light yellowish red. The experimental data were too meagre for any definite conclusions to be drawn. As there is a possibility of a detrimental effect of moisture on the strips, they should be kept in a sealed tin before they are used.

Conclusions.—There is a tendency for the non-fixed strips to be more influenced by heat and moisture than the fixed ones. Under normal conditions the heat would not operate as a factor, and with care the moisture can be controlled. Errors incurred in the fixing process are of such a magnitude that it would be best to eliminate the process.

Although, theoretically, the Eder Hecht Photometer may be faulty, as a practical instrument it is fairly efficient.

LIVINGSTON RADIO ATMOMETER.

Introduction.—The Radio Atometer is a radiometric method of measuring light. It consists essentially of two porous porcelain spherical cup atometers, one white, the other black. The light

reading is obtained by subtracting the amount of water lost from the white cup from the amount lost from the black cup.

Livingston (1935) describes the Radio Atometer as an instrument that gives an approximate measure of the drying influence of radiation from sun, sky, etc.

Theory.—In the Radio Atometer, the black sphere registers the effect of all operating atmospheric factors, while the white sphere measures the same factors with the exception of solar radiation. The difference between the water losses of the two spheres then measures rather less than 80 per cent. of the total light intensity.

The Radio Atometer is not sensitive to low light intensities. In summer in South Africa it has been found that this instrument registers no light intensity for approximately one hour after sunrise, in a fully exposed site.

Installation.—Livingston (1935) gives a very comprehensive account of the installation and operation of porous porcelain atmometers. Several points of interest have arisen in this work.

In a dry climate it is essential to soak the cups for at least one day before setting them up. The cups should be washed daily. When they are washed, they should be inverted, so that the water in the sphere prevents the dust from being driven into the porous porcelain.

By a simple experiment it was found that the size of the bore in the glass tubing used affected the rate of evaporation from the porous cup. Using two glass tubes of different bores, one with a 7 mm. diameter, and the other with a 4 mm. diameter bore, readings were taken over a period of three months. An average error of 7·8 per cent. was found. On days of rapid evaporation, the error became as large as 11·8 per cent. Therefore, it is very important to use glass tubing with exactly the same bore for both cups. This is also of importance, if several white spheres are used in different localities, for the study of evaporation.

Practical Considerations.—A serious defect from the field ecologist's point of view, is that under dense canopy the Radio Atmometer gives no light record.

Dust, hail and cold are all factors to be contended with. During freezing weather the atmometers cannot be used, even with the employment of the sealed rubber tubing. In this case the temperature inside the cup is kept abnormally low.

The black atmometer cups are more fragile than the white cups, so that more black cups should be purchased. Unfortunately, the atmometers require constant attention if reliable readings are to be obtained. The best readings are recorded by weighing the reservoirs before and after exposure.

The Effect of Environmental Factors upon the Light Value Obtained from the Radio Atmometer.—The experimental work on the effect of environmental factors upon the light values is

in no way conclusive, but only indicates the possible effects of these factors.

(a) Wind.

With an artificial fan, wind of a velocity of 67 m.p.h. was blown on to a Radio Atmometer. Readings taken during 1938 indicated that wind tends to decrease the light value recorded. As the two atmometers are at different temperatures, wind may lower the temperature of the black sphere more than that of the white. and thus decrease the light value.

(b) Temperature.

(i) *Temperature Effect on the Porous Cup.*—A Thermostat divided into two compartments, with a difference in temperature ranging from 15°C. to 20°C., was used.

The mean error was found to be 92·4 per cent. The heating conditions were abnormal, but these results indicate that the black cup absorbed much more heat that the white cup, and consequently the light value was increased. This shows that air heat may interfere very seriously with the light values recorded by the Radio Atmometer.

(ii) *Temperature Effect Upon the Reservoirs.*—To test this effect, the water in the reservoirs of a Radio Atmometer was heated, so that it was constantly 10°C. higher than the water in a control Radio Atmometer, similarly exposed. The results showed that the increased temperature of the water in the reservoir had no affect, either on the rate of evaporation, or upon the light intensity value.

Conclusions.—Not only has the Radio Atmometer theoretical and practical defects, but there are indications that the light value is interfered with by atmospheric factors.

The Radio Atmometer is an instrument of doubtful value to the field ecologist as a light recording instrument.

A Comparison of the Light Values given by the Livingston Radio Atmometer and the Eder Hecht Greukeil Photometer.

This comparison is an attempt to find out which instrument gives the best estimate of light intensity. In both cases this estimate is necessarily a rough one, but possibly sufficient for the needs of the field ecologist.

A comparison between the readings taken during 1935 and 1938 is given in the table below. Readings taken during 1936 are total daylight readings.

TABLE II.

Correlation coefficients between Radio Atmometer water loss in grams per hour and Relative Light Intensity values per hour.

Time.	Coefficient.
1935	+ 0·46 ± 0·06
1936	+ 0·44 ± 0·06
Hourly Readings, January, 1936	+ 0·78 ± 0·08

These correlation coefficients are all significant. They are poor, and this indicated that either one or both instruments do not give sufficiently accurate readings for the field ecological purposes.

Comparison using a Callendar's Pyrheliometer as a Standard.—Callendar's Pyrheliometer is a radiometric method of measuring radiant heat, in terms of heat units.

TABLE III.

Correlation coefficients found between the Light Intensity values given by Callendar's Pyrheliometer, Radio Atmometer and the Eder Hecht Photometer.

Time.	Instrument.	Correlation Coefficient.	
1936	Radio Atmometer, grams per hour	+ 0·46	± 0·17
1936	Relative Light Intensity values per hour	+ 0 65	± 0·06
Hourly Readings, 1936	Radio Atmometer, grams per hour	+ 0·90	± 0·04
Hourly Readings, 1936	Relative Light Intensity values per hour	+ 0 92	± 0·03

All these coefficients are significant.

As the Pyrheliometer and the Radio Atmometer are both radiometric methods of measuring light intensity, while the Eder Hecht Photometer is a photochemical method, it would appear from the correlation coefficients that the Eder Hecht Photometer is a more reliable instrument than the Radio Atmometer.

Total Daylight Readings.—Mean monthly light intensity values per hour, obtained from the Eder Hecht Photometer and the Radio Atmometer, are recorded below.

1938	Mar.	April	May	June	August	Sept	Oct.	Nov.
Radio Atmometer. Grams per hr.	0·666	0·955	0·671	0·876	0·979	1·047	0·841	0·816
Eder Hecht R.L.I. values per hr. ...	18·4	21·9	19·6	13·7	31·6	41·5	36 1	36·5

Conclusions.—As there are fairly high correlations between the readings from an Edar Hecht Photometer and the Pyrhelio-

meter, it would indicate that for rough ecological estimations the difference in the ratio between short and long waves can be ignored.

There are indications that certain aerial factors interfere with the light value obtained from the Radio Atmometer. It would be impossible to correct the light values, as different combinations of aerial factors would inevitably produce different reactions in the Radio Atmometer.

The Eder Hecht Photometer tends to give more reliable readings than the Radio Atmometer. Considering this and the greater practical efficiency of the Eder Hecht Photometer, field ecologists would be well advised to use the Photometer in preference to the Radio Atmometer.

The Weston Photronic Cell.

The Weston Photronic cell is a selenium cell of the rectifier type, and was invented by Bergmann in Germany. When illumination falls upon the sensitive surface, electrons escape and produce a current between the electrodes. This is measured directly by a galvanometer.

The Weston cell has a very wide commercial and scientific application. It has a range of sensitivity that makes it one of the best photo-electric cells available for general use.

For the ecologist, the Weston cell has a variety of advantages over other types of photo-electric cell. The apparatus is small and compact. The light intensity values are given directly in foot candles. The cell is sensitive mainly to the visible portion of the spectrum. Its extension into the infra-red is short and not important. Its sensitivity in the ultra violet is quite extensive if the cell is fitted with a quartz glass window.

Construction of a Cell.

The cell consists of a thin metal disc, on which there is a film of light sensitive material. The metal disc forms the positive terminal and a metal collector ring, in contact with the light sensitive surface, forms the negative terminal. The cell is contained in a black case, having a water tight glass window.

The spectral sensitivity curve given with the instrument is for an average Photronic cell. No curves are as yet available for individual cells. This is a disadvantage, as individual cells differ quite markedly from this curve. The cell surface appears to vary in its sensitivity. However, this variation is slight and for ecological work it can be ignored. The cell response to light is practically instantaneous. It has been found to record the passage of a rifle bullet through a beam of light. The Photronic cell is too sensitive for work in the field. In shaded sites it is often impossible to obtain any general impression of the light intensity values.

The cell shows a fatigue factor. When the cell is first exposed, it takes two or three minutes to reach a constant value.

Temperature is another factor that affects the sensitivity of the cell. If the cell is exposed to temperatures above 50°C., changes in the sensitivity occur. Moisture has a very harmful effect on the cell. As the cell is made water tight, this factor should not affect its use in the field.

Experimental Work with the Photronic Cell.—A Weston Photronic Cell Model 614 was used in this work. The scale of readings ranged from 0—10,000ft. candles. This range is not large enough for South African conditions, as 16,000ft.-candle readings have been obtained on summer days. With this cell an attempt was made to study the light reactions of typical grasses in South African "purple" veld.

It was a common occurrence to find the light intensity under the grasses studied reduced as much as 90 per cent. and more. Some of the grasses showed a tendency to transmit more of the longer wave lengths of light. This was found to be the case with *Hyparrhenia hirta* Stoph., *Urelytrum squamosum* Hack., and a dicotyledonous plant *Vernonia* kraussiana. *Trachypogon plumosus* Nees and *Tristachya Rehmannii* Hack ex Schug, however, tend to reflect or absorb more of these wave lengths, and transmit more of the shorter wave lengths of light. *Cymbopogon plurinodis* staph ex Burth Davey appears to transmit all the wave lengths to the same extent.

These readings were only taken during the dry season and on perfectly clear days.

Conclusions.—There seems to be little doubt that the photo-electric cell will eventually oust all other methods of measuring light intensity. For the field ecologist, the Weston Photronic cell is the best available at the present time. The Weston cell in its present form is not really suited for field ecological work. As yet, there is insufficient demand for such an ecological instrument, to allow the Weston factory to conduct the extensive research necessary to perfect such an instrument. The most fundamental defect is the extreme sensitivity of the cell. As soon as the Weston factory publish data of the spectral sensitivity of each individual cell, its value to the field ecologist will increase considerably.

The Solar Radiation Maximum Thermometer and the Naked Bulb Thermometer.

The Solar Radiation Thermometer and Naked Bulb Thermometers are simple methods of measuring light in terms of heat units. Several ecologists have found these efficient field instruments.

Solar Radiation Thermometer.—This is a black bulb maximum thermometer, enclosed in a vacuum. To eliminate air temperature effects, the reading obtained is reduced by the value

obtained from a maximum thermometer exposed in a Stevenson's screen. Theoretically, the Solar Radiation Thermometer will record about 80 per cent. of the light.

This instrument has several disadvantages. There is no standard instrument. Part of the radiant heat is lost in convection, conduction and re-radiation. The instrument is not sensitive to low light intensities. A single maximum reading gives very little indication of the light intensity during the day. The values record in degrees Fahrenheit or Centigrade are not standard light units.

Naked Bulb Maximum Thermometers.—Naked bulbs variously treated have been used successfully by several workers. Graham (1922), and Hall (1932) among them. Hall, using current thermometers, painted the mercury bulb of one black and the other white. Testing these instruments against a Macbeth Illuminometer, he found a correlation of +0·9865, ±0.0039.

These instruments have greater disadvantages than the Solar Radiation Thermometer. More radiant energy is lost in convection, conduction and re-radiation. Air temperature, wind and humidity introduce errors into the values. In rainy weather these bulbs cannot be used, as the heat is used to evaporate the water from the surface of the bulb, rather than to expand the mercury in the bulb.

Comparison between a Solar Radiation Thermometer and a Naked Bulb Thermometer.—Using a Callendars Pyrheliometer, an attempt was made to find if correcting the readings with the screen thermometer or the white bulb thermometer increased the accuracy of the light value obtained.

TABLE V.

Correlation coefficients found between Pyrheliometer readings and the readings obtained from the Solar Radiation and Naked Bulb Thermometers.

Instrument.	Correlation.	Coefficients.
Solar Radiation Thermometer ...	+ 0·79	± 0·07
Solar Radiation minus Screen Thermometer	+ 0·65	± 0·11
Black Bulb Thermometer	+ 0·65	± 0·11
Black Bulb minus White Bulb Thermometer	+ 0·63	± 0·11
Solar Radiation minus White Bulb Thermometer	+ 0·61	± 0·12
Black Bulb minus Screen Thermometer	+ 0·49	+ 0·14

These coefficients are all significant.

Comparing the readings from the Thermometers with readings from the Pyrheliometer and the Weston Photronic cell, the

following conclusions were reached. At low temperatures, correction by the screen thermometer introduces an error. At fairly high light intensities the Solar Radiation and the black bulb thermometer curve tend to follow the air temperature curve. The exposed bulbs are more sensitive to rapid light changes than the Solar Radiation thermometer. At very low temperatures, both sets of instruments are completely unreliable.

Conclusions.—Neither the Solar Radiation nor the Naked Black bulb thermometer can be called reliable light measuring instruments. The use of the Black and White bulb thermometers is not to be recommended for field light measurements.

General Conclusions.

Of the instruments under discussion in this paper, the Weston Photronic Cell and the Eder Hecht Photometer are the most efficient for field work. As rough ecological instruments these will yield useful data, only, of course, if their limitations are realised and the readings carefully interpreted.

Any further information can be obtained from the author.

Summary.

1. Several simple light measuring instruments have been discussed, from the point of view of their efficiency for field ecological purposes.

2. The Eder Hecht Photometer was found to be a more reliable instrument than the Radio Atmometer.

3. The conclusion was drawn that the Weston Photronic Cell is the best available photo-electric cell for the study of light relations in the field.

4. The Solar Radiation Thermometer and the Naked Bulb Thermometers are not recommended as reliable field instruments.

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A CONTRIBUTION TO THE ECOLOGY OF THE HIGHVELD GRASSLAND AT FRANKENWALD, IN RELATION TO GRAZING AND BURNING

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With 1 Text Figure.

Read 8 July, 1938.

Introduction.

The work embodied in this paper was carried out at Frankenwald, the Botanical Research Station of the University of the Witwatersrand, the geology, soil and vegetation of which has been described by Glover (1937).

Experiments Referred To.

A set of experiments known at Frankenwald as the " C, D and E Series," was laid out in December, 1932, by Professor John Phillips, aided by Messrs. S. M. Murray, J. D. Scott and H. Gillman. The site chosen was the most homogeneous undisturbed veld available. (Glover, l.c.).

The object of these experiments was to determine the effects of burning, grazing and trampling on undisturbed veld, over varying periods, and to study changes in plant succession brought about by these treatments. Small plots were used in this instance to test their adequacy, not as replicas of large ones, but as " result indicators " for the management of large plots.

The plan of the experiment is manifest from Fig. 1.

Since the experiments were designed for a five-year period, a permanent one metre quadrat (Murray and Glover, 1935) was listed in each plot. These quadrats were relisted at the beginning of 1938. Phenological observations were carried out on all the plots as required according to the season.

Series C.

These plots were burnt in August of each year for varying periods, commencing with successive years. Thus, in 1938, C5

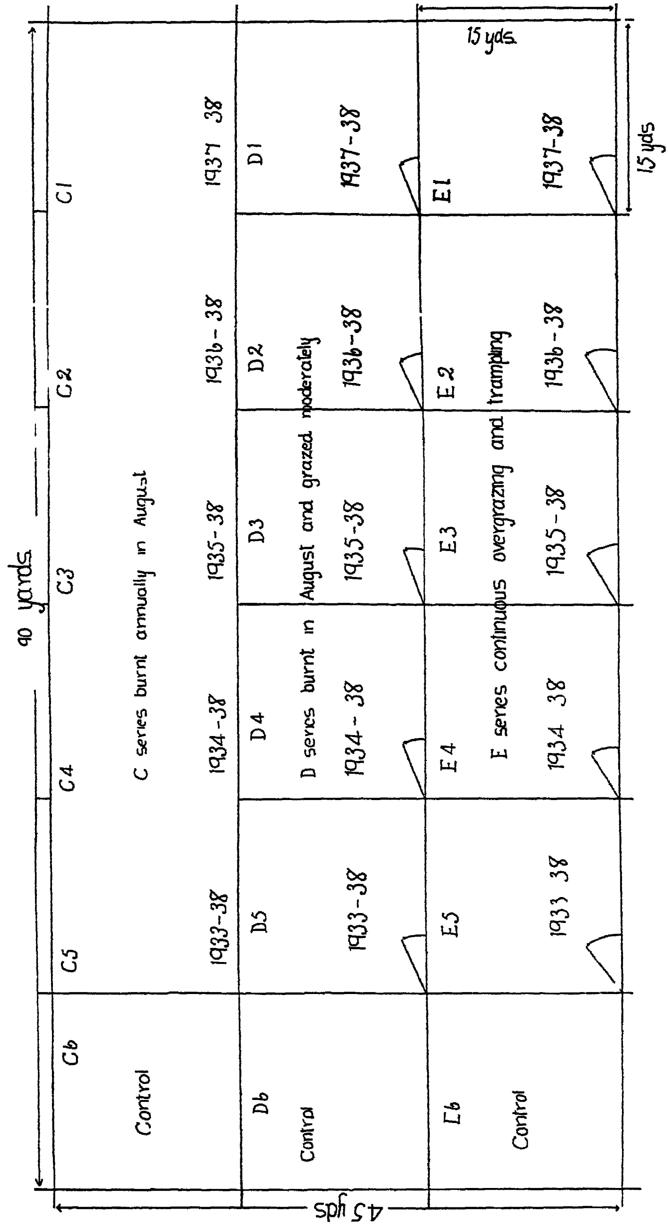

FIG ISOLATION TRANSECT SERIES C, D, E FRANKENWALD, WITWATERSRAND UNIVERSITY

Fig 1

had been burnt for five years each August, C4 for four years, C3 for three and so on. To the eye there has been very little change in any of the "C" plots since the experiment began. No other treatment but burning is used and consequently the grass grows very long and burns with much heat. This naturally would be expected to produce some effect on such a grass as *Digitaria tricholaenoides*, the root stocks of which are partially above the surface of the ground. In January, 1934, a great flush of flower heads of this grass appeared; since then the number of flower heads has diminished year by year and to the eye it would seem that in the succeeding years a large amount of this species has died out. In fact there is a general decrease of *Digitaria tricholaenoides* in all plots burnt for more than one year (see Table 1). *Tristachya hispida* shows a constant increase throughout, as does *Trachypogon plumosus*. This would appear to indicate that the treatment acts as an aid to their development. *Themeda triandra*, which is known to spread in veld burnt at Milner Park, Johannesburg, in late June, has shown no appreciable change at Frankenwald when burnt in August. *Heteropogon contortus* shows a steady decrease and the total cover shows a general decrease.

Series D.

These plots were burnt annually in August of each year and subjected at the same time to moderate grazing. It has been found that the best method is to graze as soon as the grass is long enough to be taken by cattle. Two cattle per plot for one day are sufficient to graze the veld adequately. The plots are kept under frequent observation, so that as soon as the grass is long enough it is again grazed.

It is advisable to stop grazing about the middle of February in order to allow the grass time to grow long enough to burn in August. Those plots which have been grazed longest are most even; for instance, plots D5 and D4 are more even than plots D3 and D2.

Trachypogon plumosus, Cymbopogon plurinodis, Urelytrum squarrosum, Tristachya hispida and *T. Rehmannii* are the grasses which form tussocks. Together with *Vernonia kraussii, Gnidia capitata, G. caffra* and *G. kraussiana*, which are fairly numerous, they suffer little harm from trampling, which is not excessive in series D. *Digitaria tricholaenoides* does not show signs of degeneration, according to quadrat results, even, in one case, showing an increase of 50 per cent.

Series E.

This is an overgrazing and trampling experiment and it was consequently found necessary to put three cattle in each plot for one day every week to produce the desired effects.

E5 has now been treated for five years. At the beginning of the experiment there was a small patch of *Cynodon dactylon* around an old termitarium. This patch has spread so much that almost half the plot is now covered with *Cynodon*. E5 still contains a good percentage of veld grasses, such as a broad leaved strain of *Elyonurus argenteus*, *Heteropogon contortus*, *Themeda triandra* and *Eragrostis chalcantha*, but the greater part of the grasses such as *Digitaria tricholaenoides*, *Tristachya hispida* and *Brachiaria serrata*, have been trampled out.

Here and there in the plot are large, bare patches where all the grass has been trodden out. A few annuals, such as *Chloris virgata* and *Eleusine indica* grow on the bare patches, but weeds such as *Amarantus thunbergii* and *Chenopodium ambrosoides* are conspicuously absent, probably on account of their not being able to withstand the severe trampling. *Gnidia capitata* and *G. caffra* are able to withstand the treatment fairly well, for the number and vigour of the plants have not altered.

The most striking thing about the " E " series is that the total cover on the quadrats has increased greatly on E4 and E5. This, however, is due to the spread of *Cynodon dactylon*. That almost all the original veld grasses have disappeared from E5 and that their place has been taken by pioneer grasses is noteworthy. In E4, however, most of the original veld grasses are still present although *Cynodon dactylon* has increased considerably.

Control Plots C6, D6 and E6.

In general the control plots are very rank with a large accumulation of dead material. To the eye little change is apparent. Quadrat results do show certain interesting changes and there seems to be more or less of an equilibrium, the decrease in some species being balanced by an increase in others. There is only a slight increase in total cover which is not large enough to be significant.

Some interesting changes are: a decrease of *Digitaria tricholaenoides* (3·24 per cent. average to 1·80 per cent. average); *Eragrostis chalcantha* (1·90 per cent. to 0·62 per cent.); *Brachiaria serrata* (1·07 per cent. to 0·86 per cent); and *Heteropogon contortus* (1·12 per cent. to 0·03 per cent.); an increase of *Tristachya hispidia* (2·95 per cent. to 6·81 per cent.); and *Trachypogon plumosus* (1·76 per cent. to 4·04 per cent). There was a total of 1·20 per cent. of *Themeda triandra* in the quadrats in 1933 which has since disappeared altogether. Species of *Sedge*, *Elyonurus argenteus*, *Panicum natalense* and *Eragrostis brizoides* show hardly any change at all. These figures are important in showing a trend toward increase in *Trachypogon plumosus* and *Tristachya hispida* and their high place in succession in this sub-climax stage of high veld vegetation. The species which will probably be pushed out first, as succession advances, to make way for others, are also indicated by these results.

TABLE I.—AVERAGED QUADRAT RESULTS FOR THE C, D AND E SERIES: 1933-38, FRANKENWALD.

(Figures represent % basal area in a 1-metre quadrat.)

Species	1933	1938	1933	1938	1933	1938	1933	1938
	Series C		Series D		Series E		Control	
Digitaria tricholaenoides	5·17	2·76	3·72	6·99	4·04	6·12	3·24	1·80
Elyonurus argenteus ...	0·88	0·63	1·26	0·55	0·94	0·62	1·82	1·49
Eragrostis chalcantha ...	1·22	0·32	0·93	2·10	1·46	0·38	1·90	0·62
Heteropogon contortus ..	3·76	1·79	2·84	0·81	1·81	0·72	1·12	0·03
Themeda triandra ...	1·05	0·74	0·88	0·20	1·13	0·57	1·20	0·00
Trachypogon plumosus .	1·82	3·50	2·77	1·54	2·80	0·53	1·76	4·04
Tristachya hispida ...	2·51	3·92	2·21	2 52	2 66	1·77	2·95	6·81
Cynodon dactylon ...	—	—	—	—	0 001	11·31	—	—
Eragrostis sp. ...	—	—	—	—	0·00	0·55	—	—
Total Cover ...	18·48	16·00	20·88	18·96	18 45	24·97	17·21	17·35

CONCLUSIONS.

1. Burning in August does not seem to have a detrimental effect on any important grass except *Digitaria tricholaenoides.* This grass shows a decrease in cover not only in the burnt plots, but also in the control plots. Here the decrease is probably attributable to decreased light intensities owing to rank bunch grasses.

2. *Trachypogon plumosus* and *Tristachya hispida* show a consistent increase in the controls and the C series. They appear to be high up in the sere.

3. Burning and moderate grazing appear to have no adverse effect upon the veld.

4. In series E, the plots which have had the longest treatment show the greatest increase in *Cynodon dactylon*, and in weeds. Here also the greatest decrease in the original veld grasses occurs. The treatment results in a severe set-back to succession.

5. The plots which have only been treated for one year show a remarkable similarity to the original in total cover and percentage of individual species.

6. From points made above it seems clear that small plots, of the nature of those described, are invaluable as "result indicators." Good indications of methods of treatment of large plots are obtained.

7. Complete protection for five years, and also burning for more than three years in succession in August, leads to the decrease in *Themeda triandra* in this series of plots.

8. Our experience corroborates that of West (1937), who found that many small sample plots were more valuable for this type of work than a few large ones. Thus, we feel, four ¼-metre quadrats per plot would be more useful than the present one 1-metre quadrat per plot.

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South African Journal of Science, *Vol. XXXV, pp. 280-287, December, 1938.*

PRELIMINARY STUDIES ON THE ROOT SYSTEMS OF *PENTZIA INCANA-FORMA* ON THE WORCESTER VELD RESERVE

BY

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and

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With 5 Text Figures.

Read 8 July, 1938.

Pentzia incana-forma (commonly known as *Anker Karroo*) is the only species of *Pentzia* found on the Worcester Veld Reserve, and is well grazed by stock. In continuation of the work on root studies of important plants of the Reserve (Scott and Van Breda, 1936, 1937), this species was the next to be studied with regard to its root development.

Procedure.

The method of using compressed air to uncover the roots as described by Van Breda (1937) was carried out and again found to be the best method under local conditions.

Locality: Soil Types.

Unlike the Renosterbos and Kraalbos, studied in 1936 and 1937, *Pentzia* is not at all wide spread. It is found mainly on light, loamy soils and flourishes best where these are deep. Isolated plants are found on heavier soils but they do not flourish as well as those on the lighter and deeper soils. The plant communities in which it occurs are very definitely demarcated and consist in almost every case of *Euphorbia mauritanica*, *E. burmanni*, *Asparagus africanus*, *Pteronia incana*, *Cotyledon paniculata*, *Pteronia paniculata*, *Lycium arenicolum*, *Drosanthemum sp.*, *Galenia africana*, and *Rushia multiflora*.

Results.

The species has an extensive root system and, as it is stoloniferous, the stolons root readily on touching the ground under favourable circumstances—loose, sandy soils—and huge plants with masses of ramifying roots are formed.

Under normal arid conditions where the plant is usually found, the root systems are similar and characteristic as regards depth of penetration and position of roots. In some cases

investigated where the surface was loose and friable but the subsoil shallow and hard, the mature plants were found to be surviving entirely in the surface two feet of soil. Under such conditions, it does not thrive well. The roots of the plant are woody, light brown in colour and the major roots are usually covered with a thick layer of loose threadlike bark.

During the first few months of growth of a seedling plant, under normal soil conditions, a prominent tap root is formed which tapers fairly rapidly and gives off a number of laterals on its downward course. At an average age of 4-5 months, the taproot usually splits up into two or more branches at a depth of 1 to 1½ feet but the terminals of these branches may be at a depth of 3 feet or more. From this age the chief development of the root system seems to take place an inch or two below the surface where three to six major laterals develop (see fig. 4C) and numerous adventitious roots are given off from the crown of the plant which, as the plant matures, grow into a dense cluster (see fig. 4C). The major laterals more often than not grow to a greater diameter than the taproot and, when the plant is mature, the taproot shows no prominence below the surface foot of soil. The taproot and major laterals in the mature plant vary from 14 mm. to 1 cm. in diameter while the remaining mass of roots usually vary from 0·5 mm. to 3 mm. in diameter. (See fig. 4B). The crown of the mature plant at this stage may measure from 7·5 to 15 cms. in diameter but this crown usually consists of ten to twenty or more sections varying from a few millimetres to 4 cms. in diameter. Actually they appear to be individual plants which have detached themselves from the older original stem and just loosely held together.

The adventitious roots as well as the majority of the surface laterals travel obliquely to horizontal distances of 1½ to 2½ feet from the base of the plant, within the surface foot of soil, and then grow down whilst others may grow more or less vertically downward reaching to depths (which vary with subsoil moisture and soil structure) 5 to 9½ feet. The taproot and major laterals rarely dominate below 1½ feet as, before this depth is attained, these roots have split up and have given off a number of thin laterals and branches which penetrate the soil vertically and all of which remain less than 2 mm. in diameter.

The stolons give rise to plants with numerous adventitious roots which may number up to 35 at one spot. The stolons which have become anchored and formed new plants usually detach themselves from the mother plant within 6 to 10 months and become individual plants. (See fig. 4C). Their adventitious roots may penetrate the soil to the maximum depth of penetration. The roots of the plant as well as the adventitious roots rarely branch to any extent below 18 inches while the majority penetrate down giving off short laterals at intervals of ½ to 2 inches which only occasionally measure more than 2 inches in length. The main penetrating roots usually terminate by breaking up into fine branches.

The penetrating roots, fine branches and threadlike adventitious roots are all remarkably well covered with fine root hairs which may occur along the entire length of these fine roots, but are more abundant where the soil is better aerated and where the soil is moister.

In the case of plants growing under moderately moist soil conditions (see figs. B113 and 4A), the development of the root is very similar to that in plants growing under arid conditions except that the roots do not penetrate so deeply and *practically the whole root system is covered with fine root hairs.* The whole growth, however, is faster and more stolons are formed which give the whole root system a white frosty appearance. These root hairs appear to be fairly permanent as they are easily retained on a root specimen when removed from the soil and they are not confined to areas just a short distance behind the rootcaps. In general, with the exception of this formation of dense roothairs under moist conditions, the development of the root systems of *Pentzia incana-forma* is characteristic as described above.

Discussion.

The species is stoloniferous and has a massive root system and, as it usually dominates on a friable easily erodable soil, it is valuable in soil erosion prevention. The comparatively shallow depth of penetration of the roots (compared with *Elytropappus* and *Galenia*) probably accounts for the fairly rapid drying up of the plant during drought while the extensive root system and the immense amount of roothairs would account for its rapid recovery after drought.

Summary.

The root systems of various plants of *Pentzia incana-forma* growing under various conditions, are described and figured. The roots do not penetrate to such depths as those of the Renosterbos and Kraalbos, described in previous papers, but the development of the roots appears to be characteristic under various conditions. The shallow rooting probably accounts for the tendency to dry up early during drought, while its well developed masses of root hairs make for rapid recovery with small amounts of rain. The habit of the plant and the soils on which it thrives best should make it of use in combating soil erosion.

Acknowledgments.

The writers wish to thank the Chief of the Division of Plant Industry for facilities provided for this work and for permission to publish this paper.

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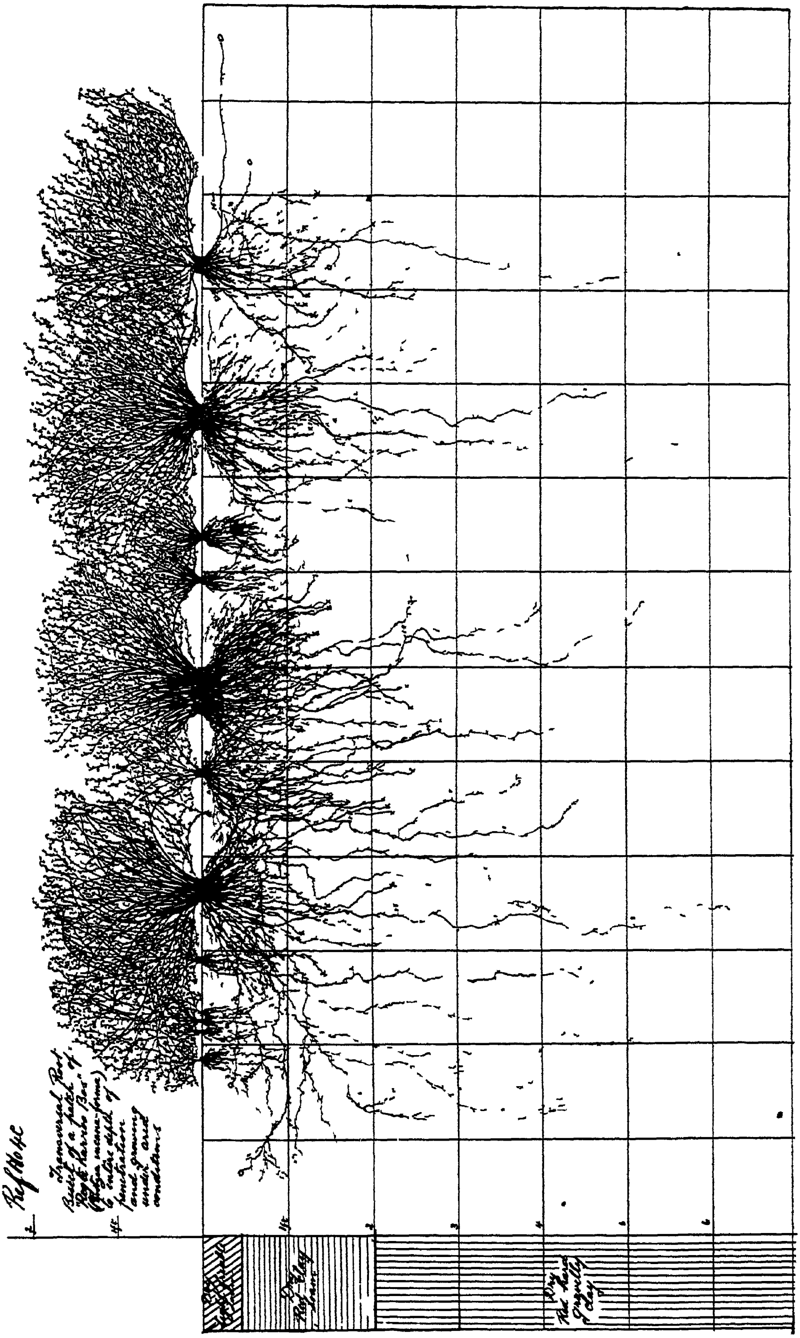
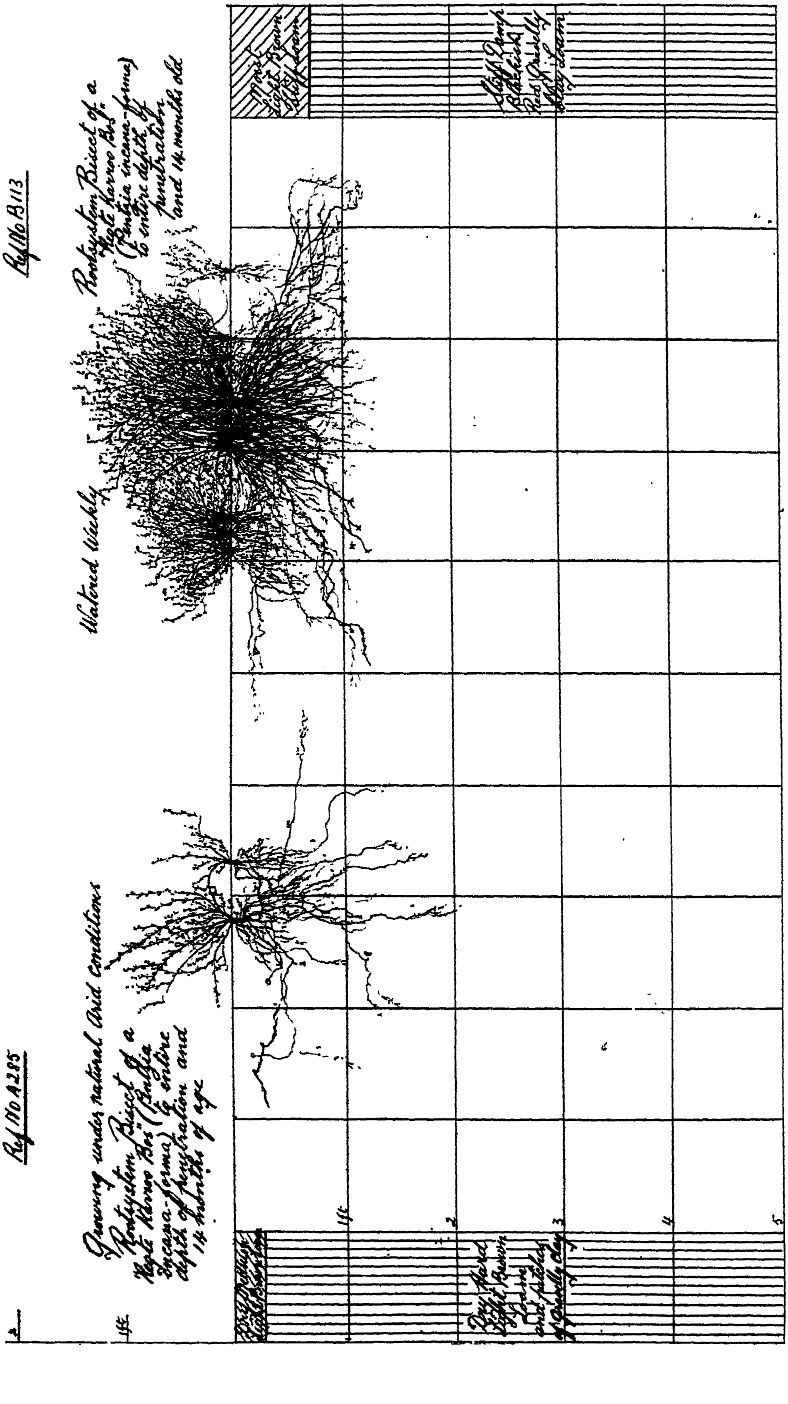
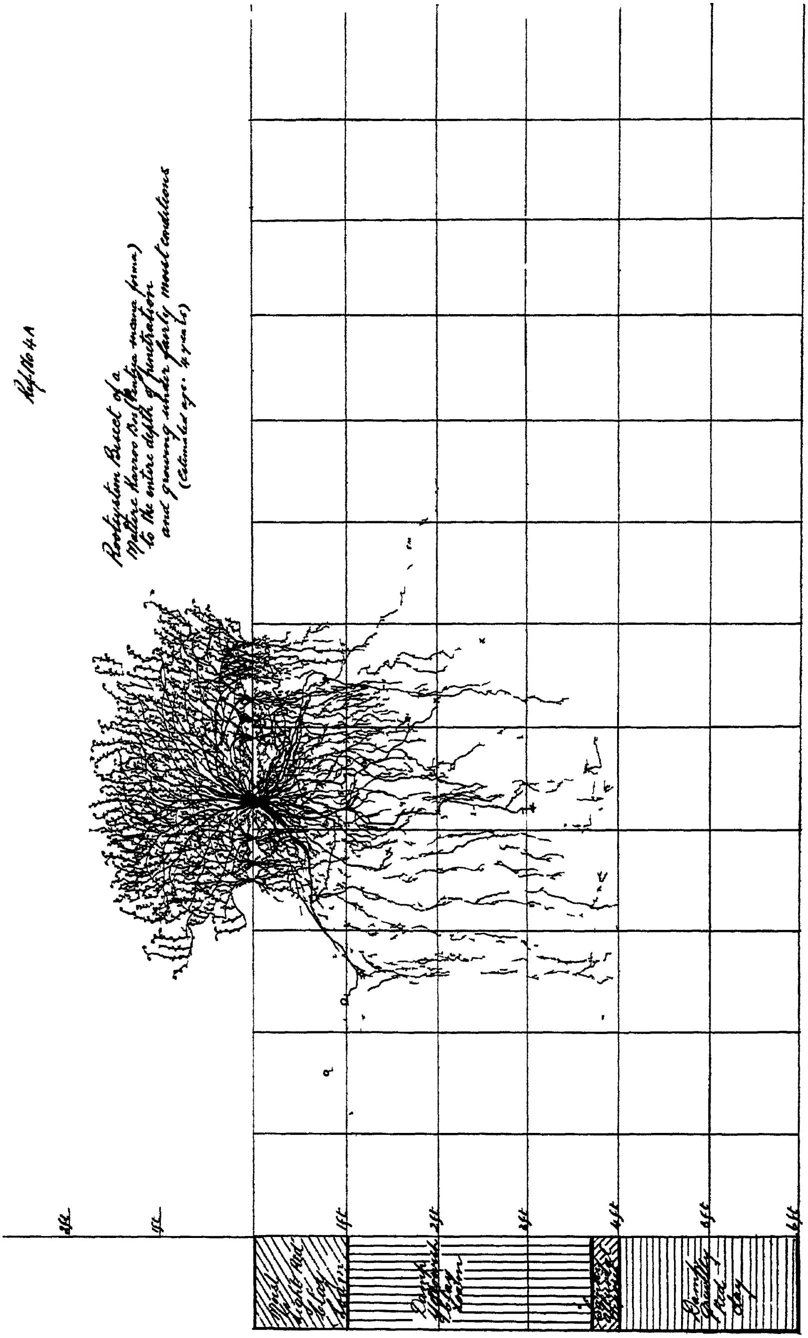
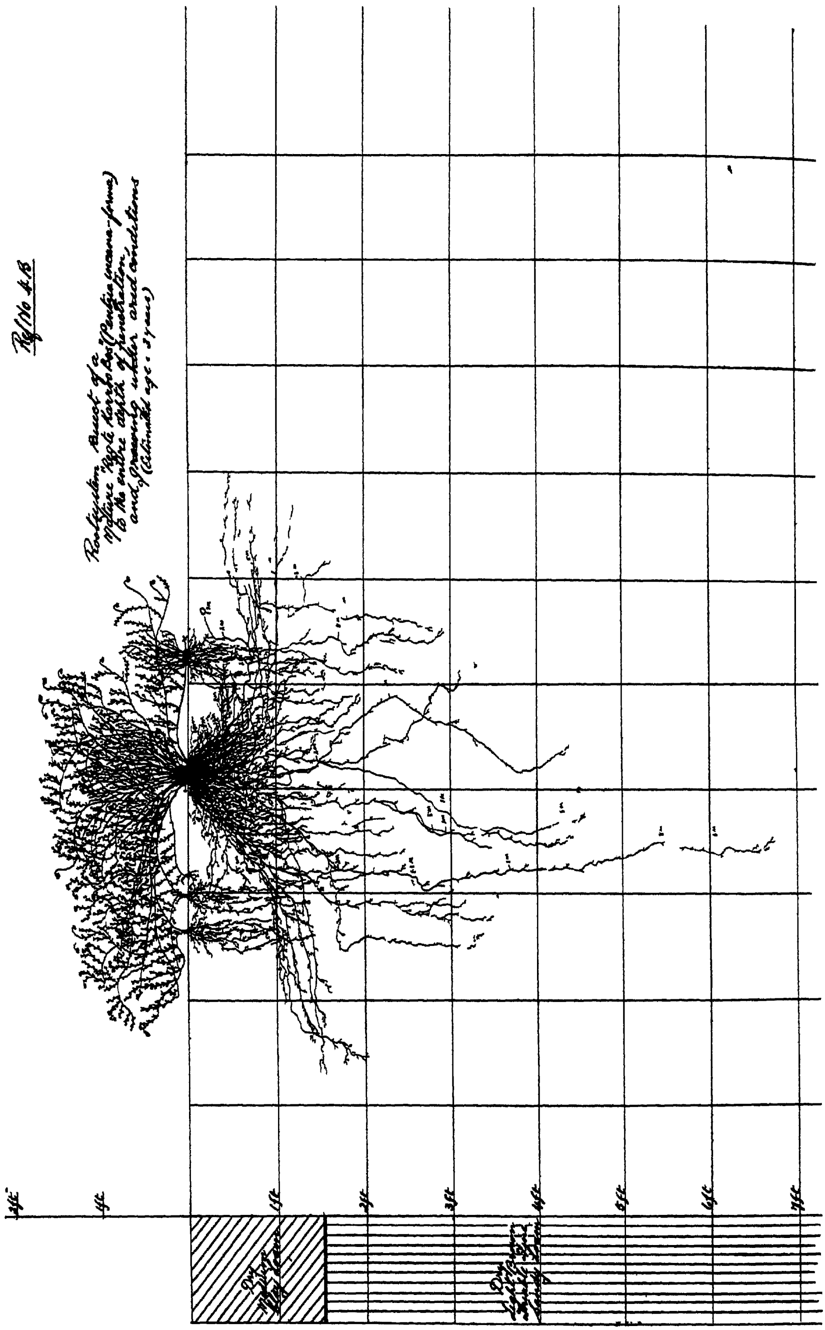
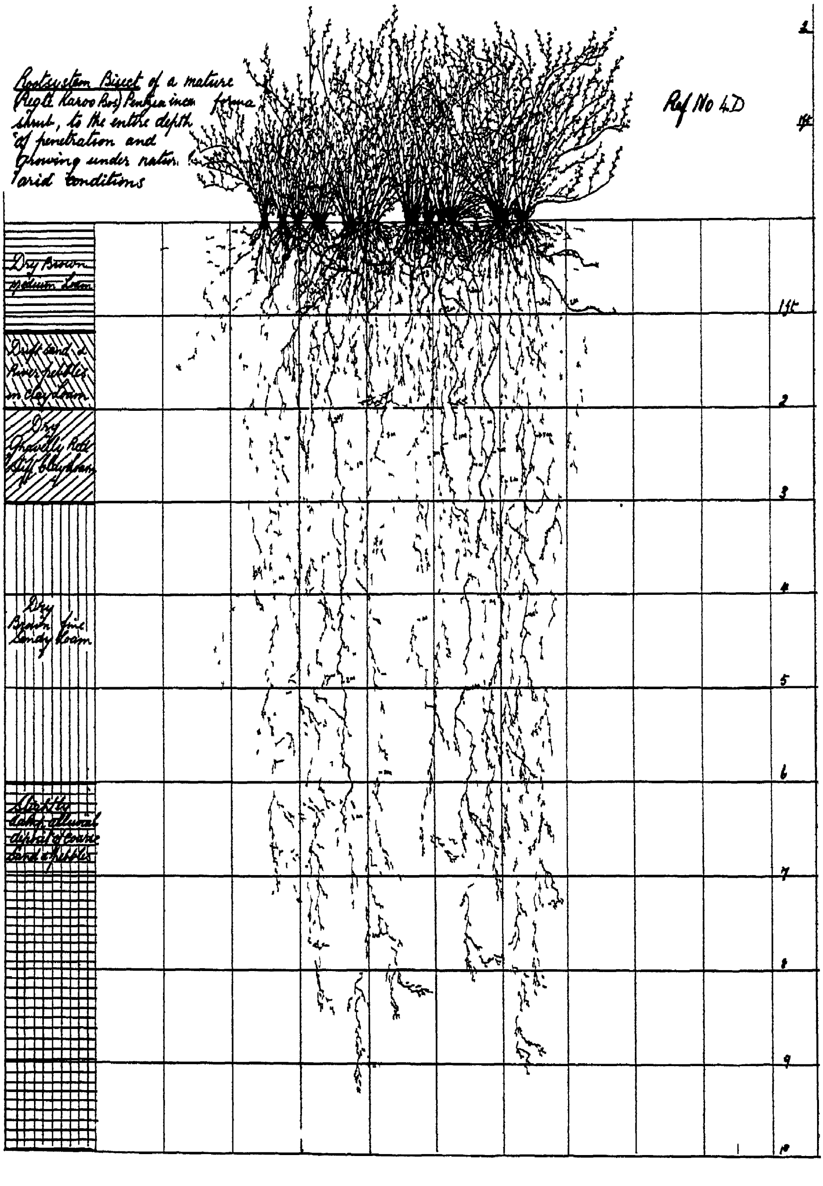




Ref No A285
Growing under natural Arid conditions
Rootsystem Bisect of a "Regte Karroo Bos" (Pentzia incana-forma) to entire depth of penetration and 14 months of age
Ref No B113
Watered Weekly
Rootsystem Bisect of a "Regte Karroo Bos" (Pentzia incana-forma) to entire depth of penetration and 14 months old
Moist Light Brown Stiff Loam
Stiff Damp Blackish Red Gravelly Clay Loam
Dry Hard Light Brown Loam and patches of Gravelly Clay
1ft
1ft
2
3
4
5


Ref No 4A
Rootsystem Bisect of a
Mature Karroo Bos (Pentzia incana forma)
to the entire depth of penetration
and growing under fairly moist conditions
(Estimated age: 4 years)
1ft
2ft
3ft
4ft
5ft
6ft


1ft
2ft
3ft
4ft
5ft
6ft
7ft


Rootsystem Bisect of a mature
(Regd. Karoo Bos) Pentzia incan forma
shrub, to the entire depth
of penetration and
growing under natur.
arid conditions
Ref No 4D
1 ft
2
3
4
5
6
7
8
9
10
Dry Brown medium Loam
Dry sand & river pebbles in clay loam
Dry Gravelly Red Stiff Clay Loam
Dry Brown fine Sandy Loam
Slightly damp alluvial deposit of coarse sand & pebbles

South African Journal of Science, *Vol. XXXV, pp. 288-297, December, 1938.*

AN INVESTIGATION OF THE INTERRELATIONSHIPS OF THE VEGETATION, SOILS AND TERMITES *

BY

JEAN M. MURRAY.

With Graphs I and II.

Read 8 July, 1938

ABSTRACT.

INTRODUCTION.

The primary object of this investigation was to learn how the vegetation, soils and termites in certain studied areas were interrelated.

Most of the observations were made on Frankenwald, the Botanical Research Station of the University of the Witwatersrand. Less detailed work was carried out at Drylands, near Pretoria; at Leeuwkuil, the Government Pasture Research Station near Vereeniging, and at Maniston Farm, near Val. Notes were taken at Rust der Winter (Government Research Station), and also near the Pretorius Salt Pan in the Bushveld of the Transvaal.

This paper is divided into the following three parts:—

1. Twelve termite species—their nest structures, their habits and their fungal and animal associates.
2. Soils—their composition in two different vegetation types, and their composition in termitaria.
3. Vegetation—and its association with termites.

PART I.

A. *Some termite habits and nest structures.*

Termite collections were made from the studied areas and these were identified by Professor Emerson of Chicago and by Mr. W. G. H. Coaton of the Department of Entomology of Pretoria.

The following termite species have been observed in the investigated areas and their nest structures and habits have been described with the aid of 34 photographs and several diagrams:—

Group I.—Grass and humus eaters.

(a) *Cubitermes bilobatus.*

(b) *Hodotermes* (H.) *mossambicus* sub sp. *Transvaalensis* Fuller.

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* This paper is a summary of a paper for which the author was awarded the British Association Junior Medal, 1938. The full report is on file at the Botanical Research Station, Frankenwald, University of the Witwatersrand.

(c) *Microcerotermes choanensis* Fuller.
(d) *Microcerotermes apricitatus* Fuller.
(e) *Trinervitermes havilandi* Fuller.
(f) *Trinervitermes pretoriensis.*

Cubitermes bilobatus and *Trinervitermes havilandi* were the species considered as typical "Mound builders," as the main parts of their nests are above soil level, and they are in the shape of mounds. The two species of *Microcerotermes* were found at the bases of plants near the soil surface.

Group II.—Fungus growers.

(a) *Macrotermes natalensis Haviland.*
(b) *Microtermes havilandi.*
(c) *Microtermes* sp.
(d) *Odontotermes* (O) *badius* Haviland.
(a) *Odontotermes latericius.*
(f) *Odontotermes transvaalensis.*

Macrotermes natalensis and *Odontotermes* (*O*) *badius* although they do build hummock-shaped mounds (*Macrotermes natalensis* also builds conical moulds) have been classed as subterranean termites, as have all the other termite species of Group II, and also *Hodotermes mossambicus* of Group I. Their main nest structures are below the soil surface.

From the description of these nest structures it is realised that:—

(1) There are two types of termitaria in the studied areas. (a) Typical mound-like structures with the actual nests above or very nearly above soil level. (b) Subterranean nest structures.

(2) The total area occupied by the termitaria of both types is considerable. At Witkoppies, near Irene, Transvaal, the approximate area occupied by 218 *Trinervitermes havilandi* mounds in one acre was 119 square yards.

(3) The structures of both types of termitaria are quite distinct from the surrounding soil structure and consequently the soil and vegetation is affected to a considerable extent.

B. *Fungal Associates.*

All the fungal specimens collected by the writer have been investigated and determined by Miss Bottomley, Division of Plant Industry, Pretoria.

The fungus of termite fungus gardens appears to be completely unidentified throughout the world, as it cannot be grown in cultures.

Xylaria nigripes and Xylaria sp. appear to be the fungi most often associated with the nests of termites.

Podaxon sp. (carcinomalis) is a common form associated with *Trinervitermes havilandi.* Other fungal associates were *Cordyceps, Mycenastrium corium, Schulzeria umkowaan* and *Collybia albuminosa.*

C. *Animal Associates.*

The most abundant termitophiles were found to be ants of various species, of which *Plagiolepus custodiens* is the most important.

Coleopterous adults and larvae are common.

Birds frequent termitaria, and it is suspected that there is some chemical substance in these termitaria which is sought after by cattle.

PART II.

Soils: their composition in two vegetation types and their composition in termitaria.

The composition of the soil will be discussed under three headings:—

1. The soil composition of adjoining strips of Purple veld (veld which has been undisturbed by excessive burning, grazing, etc.) and *Hyparrhenia hirta* veld, and the composition of the mound builders' termitaria in these two veld types.

Site.—The adjoining strips of Purple veld and *Hyparrhenia hirta* veld each occupied an area of approximately one acre, and they lay on a slight north-east slope on Frankenwald (West). The Purple veld was fairly pure, but the *Hyparrhenia* veld was found growing on an area which had been partly occupied by native huts forty years previously, and therefore there were patches of *Eragrostis* sp. and *Cynodon dactylon.* The soil is made up of decomposing granite. The actual site of sampling was in the line of contact between the two veld types, which were pure in this region.

Methods.—The samples were taken a yard apart, at depths of two inches and nine inches along the boundary of a rectangle, which was nine yards broad by twenty-one yards long. 480 samples were taken in 2½ days during which there was no rain.

Ten termitaria (7 *Cubitermes bilobatus* and 3 *Trinervitermes havilandi*) were sampled in each veld type. The holard and pH samples were taken at a depth of two inches.

The samples were tested for:—

(a) Holard (% moisture $= \dfrac{\text{loss of weight on drying} \times 100}{\text{dry weight of soil used}}$

(b) humus (% humus $= \dfrac{\text{loss on ignition} \times 100}{\text{dry weight of soil used}}$

(c) pH (International Quinhydrone method, with the saturated calomel electrode and the Cambridge Hydrogen Ion Potentiometer.)

(d) Nitrogen (Kjeldahl method).

(f) Maximum water retaining capacity.

(M.W.R.C. (%) $= \dfrac{\text{saturated soil} - \text{dry soil} \times 100}{\text{dry soil used}}$).

The significance of the results was calculated statistically.

(These same soil tests were used in all the following soil experiments which are described under headings 2 and 3).

Conclusions.

(i) There is a definite difference in the composition of the soil in the veld types in different stages of plant succession. Purple veld (the climax veld type) is found to have a greater percentage of

(a) Holard.
(b) Acid.
(c) Nitrogen.
(d) Colloid.

The fact that Hyparrhenia veld had a slightly higher M.W.R.C. and humus percentage might be due to the previous inhabitation of the site. There is a significant correlation between the M.W.R.C. and humus.

(ii.) There is not a significant difference between the composition of the termitaria in the two veld types. It can be concluded, therefore, that termites of the same species treat different soils in a manner which eventually gives rise to termitaria of a fairly uniform chemical and physical composition. The composition of the termitarium appears to vary with the termite species.

(iii) There is a difference between the composition of the termitaria and the surrounding soils. Termitaria have a higher percentage of:—

(a) Humus.
(b) Nitrogen ($\pm$ double soil).
(c) Colloid ($\pm$ double soil).
(d) M.W.R.C.

The percentage holard and acidity is slightly greater in termitaria, although it is not significantly so.

2. *The soil composition of subterranean termitaria.*

Methods.—Soil samples were taken along the 25 yard bisect lines of two *Macrotermes natalensis* hummock-shaped mounds, at yard intervals and at depths of six, eight and twelve inches. (Depths varied with different sample types).

Conclusions.—The percentage of the following properties tended to rise towards the centre of the mounds:—

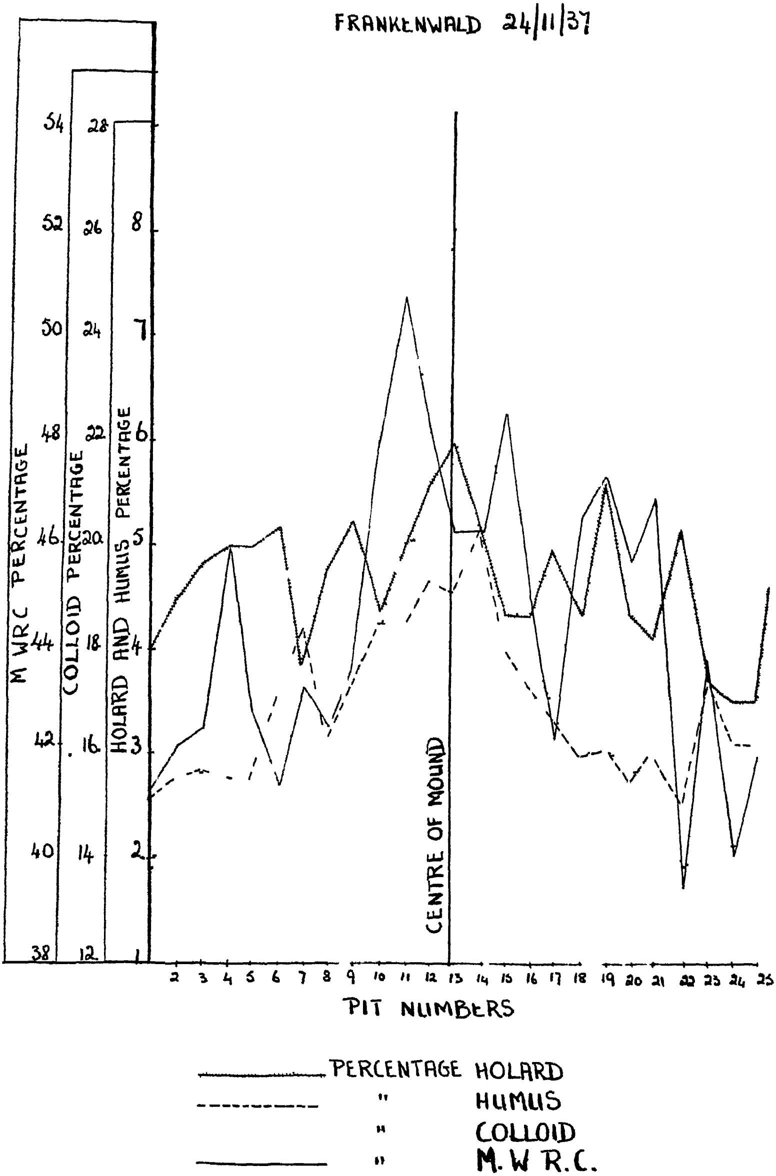
Holard.
Humus (fairly definite).
Nitrogen.
Colloid (very definite).
M.W.R.C.

(See Graph I).

GRAPH I

A GRAPH SHOWING THE TREND OF FOUR SOIL CONSTITUENTS IN SAMPLES TAKEN ALONG A BISECT LINE THROUGH A MACROTERMES NATALENSIS MOUND AT A DEPTH OF 6 INCHES

FRANKENWALD 24/11/37



The acidity of the soil did not rise significantly towards the centre of the mound, but the pH of the *Macrotermes natalensis* fungus garden was found to be 3·82.

The percentage humus of the *Macrotermes natalensis* fungus garden was 85·92, while the surrounding nest soil had a humus percentage of approximately 6·32.

In one case the holard of the fungus gardens was found to be 42·66 per cent., while that of the surrounding nest soil was 13·55 per cent. The holard of the soil at a depth of four inches was only 4·89 per cent.

3. *Some general experiments on soils affected by and associated with termites.*

(a) Areas denuded of their vegetation by termites (*Hodotermes mossambicus* sub sp. *transvaalensis*) have a lower percentage holard than unattacked areas, covered with the natural grasses.

(b) Although cattle are found to lick termitaria, there is no significant amount of chloride in the Trinervitermes mounds.

(c) Mr. Coaton found that after baiting *Hodotermes mossambicus* with arsenic-poisoned grass, the nest carton contained arsenic, as did the dead and dying termites.

General conclusions drawn from Part II.

The composition of termitaria is even richer than that of Purple veld soil (Climax veld soil), but the fertile constituents appear to be unavailable to plants owing to their chemical combinations. The living mounds in the studied areas were never covered with luxuriant vegetation.

Part III.

Vegetation and its association with termites.

A. *Veld management and termites.*

The writer aimed at finding out whether different veld treatments affected

(a) the abundance of termites,
(b) the distribution of different termite species,
(c) termite attack on vegetation.

Methods.—The veld treatments which were considered were *ploughing*, *fertilising*, *grazing* and *burning*. Large areas undergoing these treatments were minutely surveyed and the number of termitaria was carefully noted and described.

Conclusions.

(a) The abundance of termites does appear to be affected by the different veld treatments. Ploughing destroys the smaller termite mounds. Natural manures attract termites. Overgrazing appears to decrease the number of termite mounds. Late burning may facilitate the formation of numerous new termite colonies.

(b) Veld treatments do affect the distribution of termite species to some extent. By ploughing, only the subterranean termites are allowed to live. In natural manures termites of many species are localised, that is, in their search for food. Overstocking destroys the smaller mounds, but there is every possibility that the larger *Trinervitermes havilandi* mounds remain undisturbed. Burning might increase the possibility of the entrance of certain termite species to the soil, according to the time and habits of termite flight and to the time of burning.

(c) Termite attack on the vegetation will be decreased by fertilisers if these render the plant more able to withstand termite attack. When there is manure available termites will probably choose this rather than the wholly undigested plant materials. Plants may be weakened immediately after firing, and consequently they may be attacked more vigorously by termites such as *Microcerotermes apricitatus* at Drylands.

B. *Termites in different vegetation types.*

It was the aim of the writer to find out:

(a) Whether the abundance of termites varied in the different veld types.

(b) Whether this probable variance was due to certain termite species attacking or associating with certain plant species.

(c) Whether any parallel could be drawn between the stages of secondary plant succession and the abundance of termite species.

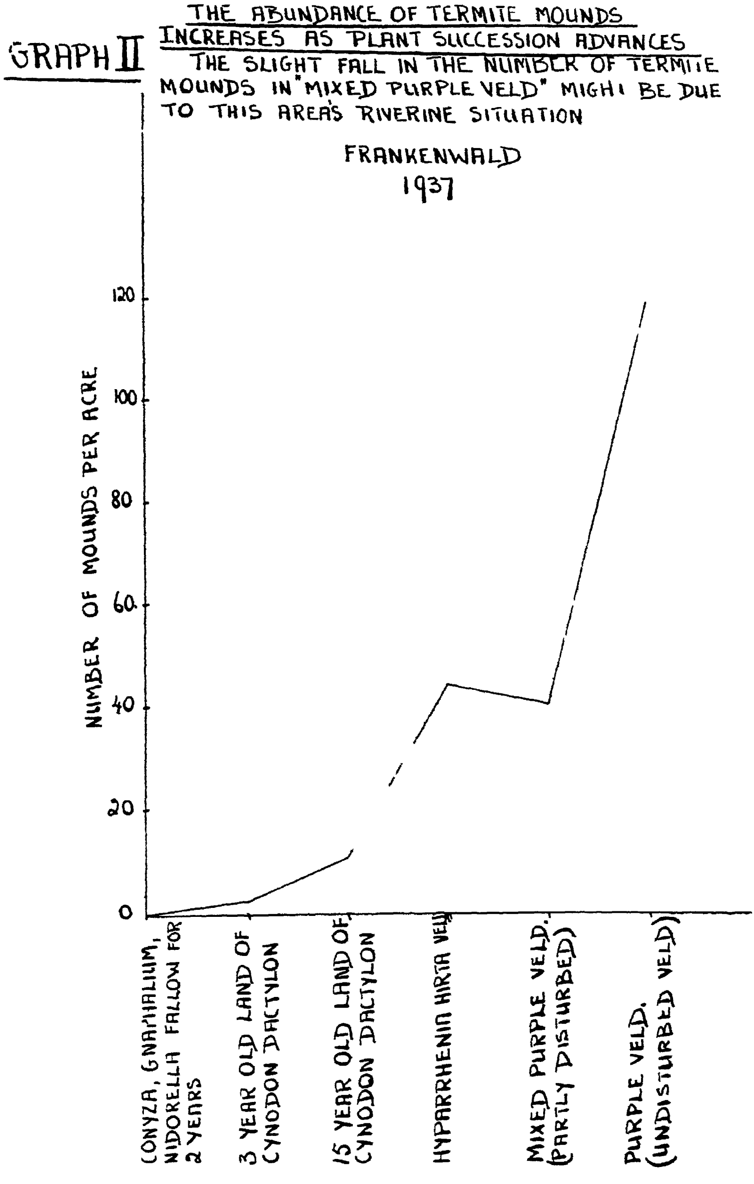
Methods.—Areas of the following vegetation types were dealt with in the same manner as the previously described veld treatments:—1. *Conyza ambigua*, *Gnaphalium undulatum*, *Nidorella anomala* and *Cynodon dactylon*. 2. *Cynodon dactylon*. 3. *Hyparrhenia hirta* 4. *Themeda triandra*. 5. Mixed Purple veld (Climax and other grasses). 6. Purple veld (undisturbed veld). 7. Riverine vegetation. 8. Indigenous bush and trees. 9. *Stoebe vulgaris*. 10. Exotics.

Conclusions.

(a) Termite abundance varies in the different veld types and it varies in the same veld type in different geographical areas.

(b) Termite structures are most frequently associated with the most abundant plants of the region, and although *Microcerotermes choanensis* attacks the underground portions of plants it does not appear to confine its attacks to any one plant species. Exotics appear to be more heavily attacked than indigenous plants.

(c) Termite abundance increases as secondary plant succession advances. This was found to occur quite definitely in the first six vegetation types mentioned. These constitute six succeeding seral stages on Frankenwald. This is thought to be due to an increase in the binding of the soil particles which renders the soil texture more suitable for termite habitation. (See Graph II).


GRAPH II
THE ABUNDANCE OF TERMITE MOUNDS INCREASES AS PLANT SUCCESSION ADVANCES
THE SLIGHT FALL IN THE NUMBER OF TERMITE MOUNDS IN "MIXED PURPLE VELD" MIGHT BE DUE TO THIS AREA'S RIVERINE SITUATION
FRANKENWALD
1937
NUMBER OF MOUNDS PER ACRE
120
100
80
60
40
20
0
CONYZA, GNAPHALIUM, NIDORELLA FALLOW FOR 2 YEARS
3 YEAR OLD LAND OF CYNODON DACTYLON
15 YEAR OLD LAND OF CYNODON DACTYLON
HYPARRHENIA HIRTA VELD
MIXED PURPLE VELD. (PARTLY DISTURBED)
PURPLE VELD. (UNDISTURBED VELD)

FINAL CONCLUSIONS DRAWN FROM PARTS I, II AND III.

With the conclusions already drawn in Parts I, II and III, the writer aims at finally concluding whether the effects of termites on the vegetation and soils are in any way beneficial, or whether they are totally detrimental

Detrimental Effects.

1. In Part I it was pointed out that both subterranean termitaria and termite mounds occupy a considerable area which must have some significance.

2. From Part II it was concluded that termites in some way change the fertile surrounding soil into the sterile soil of their termitaria. On this soil very few plants are able to grow.

3. In Parts I and III it was seen that termites attack the vegetation to a considerable extent. This attack often causes the death of plants. Owing to the harvesting habits of termites the grazing value of the veld is reduced and soil erosion is encouraged. The death of valuable trees and plants is of considerable economic importance.

Beneficial effects.

1. From Parts I and II it will be realised that the aeration of the soil must be increased by termite workings.

2. In Part II it was shown that termites in their termitaria increased the percentage holard, humus, nitrogen, colloid and the maximum water retaining capacity. The beneficial increase of these factors appears to have been rendered sterile for the time being, but the writer feels that eventually, when the termitaria break down, oxidise and completely disintegrate, these sterile termitaria will be changed into doubly fertile soils.

From this investigation the writer finally concludes that certain termite species when alive and active, are definitely detrimental to the vegetation and soils. but when the individual termite colonies eventually die out, the termitaria, in their final stages of disintegration, will return all they have previously robbed from the soil and its vegetation.

ACKNOWLEDGMENTS.

Sincere thanks are due to Professor John Phillips for his advice and sympathetic guidance throughout this investigation.

The writer would also like to thank Dr. I. B. Pole-Evans for making possible the co-operative work of Mr. Coaton and other workers of the Division of Plant Industry.

The writer is greatly indebted to Prof. A. Emerson of the University of Chicago for all his assistance and interest.

Mr. W. G. H. Coaton, Miss Bottomley and Mr. Munro of the Division of Plant Industry are to be thanked for their invaluable

assistance in naming the writer's specimens and for explaining many of the writer's problems.

Dr. H. Weinmann and Mr. A. H. Bunting have helped the writer a great deal in her chemical problems.

Thanks are due to Mrs. Brown of the Mines Department, to Miss L. Cook, Mr. H. B. Gilliland, Mr. P. Glover, Mr. R. Story, Mr. H. van Rensburg, of the Witwatersrand University, to Dr. N. L. Murray, to Dr. I. H. Boas, Chief of the Division of Forest Products in South Melbourne, to the Agricultural Department of the Federal Malay States, and to Prof. T. Snyder, Senior Entomologist of the United States Department of Agriculture in New Orleans, for the information and literature they have placed at the disposal of the writer.

Mr. R. Rose-Innes is to be thanked for his co-operative and collaborative work.

Finally the writer wishes to thank the typiste.

As this is a summary no Bibliography has been given.

A FIELD METHOD FOR THE TRANSPIRATION RATE OF GRASSES

BY

A. W. Bayer.

Natal University College, Pietermaritzburg, South Africa.

Read 8 July, 1938.

Abstract.

Summary.

An account was given of a simple field method for measurement of transpiration rates. The transpiring leaves are enclosed within weighed test tubes containing strips of filter paper impregnated with dry calcium chloride. Transpired water vapour is absorbed, and by noting the gain in weight of the test tubes, the time for which the leaves were enclosed, and the leaf area, the transpiration rate for unit area in unit time can be calculated.

A few applications were given for measurements of the transpiration rates of some common Natal grasses

South African Journal of Science, *Vol. XXXV, pp. 298-299, December, 1938.*

EUPHORBIA FASCICULATA THUNB. AND *E. SCHOENLANDII* PAX

BY

R. A. Dyer,

Botanist, Division of Plant Industry, Pretoria.

With 2 Plates.

Read 8 July, 1938.

The identity of these two species of *Euphorbia* was confused by Brown (1).

The name *E. fasciculata* was first published by Thunberg (2) with the description: " E. fruticosa teres inermis, ramis apice aggregatis." In 1823 (3) the supplementary information "Flores umbellati umbella simplici " was given. Boissier (4) followed the amplified description and stated that the species was not represented in Thunberg's Herbarium. It was present when Brown revised the genus (1), and I examined it at Uppsala in 1933.

Brown, l.c. noted, "Thunberg's type is at present in his Herbarium, and consists of a small plant sliced down the middle into two portions, the specimen is not in flower, but three detached umbels belonging to another species are fixed to the same sheet, these are evidently the peduncles and umbels described by Schultes. These umbels, however, belong to some species allied to *E. mauritanica* Linn., and have no connection with *E. fasciculata* Thunb. The other specimens and the photograph quoted above (i.e. by Brown) are most certainly identical with *E. fasciculata*, Thunb., and have enabled me to give a more complete description of it; the Woodifield (Woodsfield in error) specimen is the type of *E. Schoenlandii* Pax (5). The manner in which the peduncles arise from a slight cavity behind the spines is very remarkable and quite unlike the mode of flowering in any other species I have seen. The spines are more erect and incurved on some plants than on others."

I have examined two living plants of *Euphorbia* which, as far as comparison is possible, agree in every essential detail with Thunberg's type specimen, i.e. including the inflorescences which Brown considered belonged to an *E. mauritanica*-like species. The pseudo-umbel of typical *E. fasciculata* is remarkably similar to that of an allied species *E. restituta* (Plate II, Fig. 1) described by Brown, l.c. 339, and it is the more surprising therefore that he should have been so emphatic about what he considered Thunberg's error. Brown, l.c. 340, based his description of *E.*

[Photo C G Alm

Euphorbia fasciculata Thunb
(Half of type specimen at Uppsala)

To face Page 298

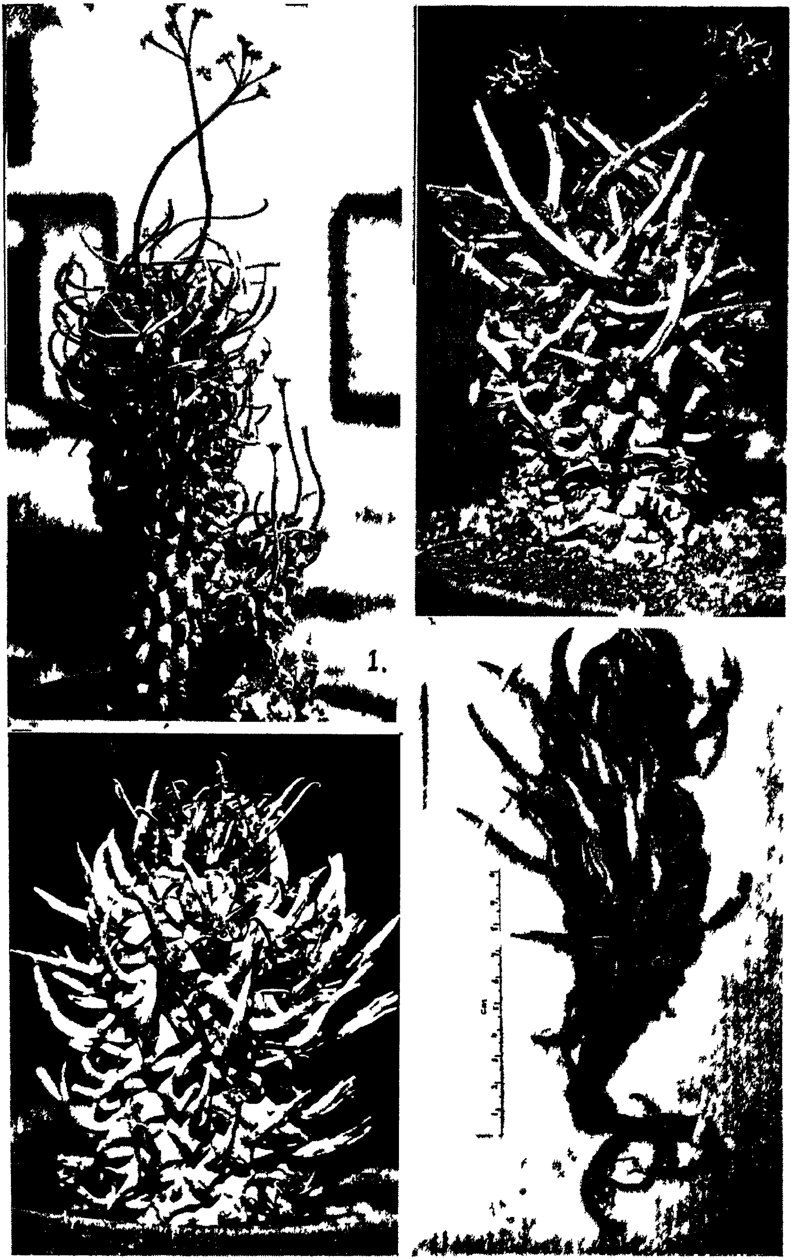


Fig. 1 —*Euphorbia restituta* N E Br , 2, *E fasciculata* Thunb , 3, *E Schoenlandii* Pax , 4, *E Schoenlandii* Pax (part of type)

To follow Plate I

fasciculata to some extent on Thunberg's type, but admittedly mainly on specimens whose inflorescence was markedly different. The latter as he said, included the type specimen of *E. Schoenlandii* Pax.

Professor N. E. Svedelius supplied me with a photograph of the type specimen of *E. fasciculata* Thunb. at Uppsala, Plate I. Unfortunately, the tubercular structure of the stem has been largely destroyed during preservation, and the inflorescence has been damaged by insects. The arrow in pencil was made by Brown. Compare the figure with that on Plate II., Fig. 2. Though the peduncles of Thunberg's specimen are not actually attached to the body of the plant, the marked general similarity between them and those of the living plant justifies the assumption that they belong to the same species. The stout curved peduncles are terminated by a pseudo-umbel of about five pedunculate bisexual involucres, occasionally surrounding a sessile deciduous male involucre. The involucre consists of a cup-shaped base with four or five subentire involucre glands and five fimbriate lobes. The ovary is well exserted on a curved, slender pedicel.

In Plate II, Fig. 3, note the incurved, sterile, sharply pointed peduncles. Some have short fertile peduncles produced immediately below them and emanating from within a common tubercle. The cyathia are either male or bisexual on the same plant, one to three on each peduncle. The involucre consists of a cup-shaped base with five toothed glands and five fimbriate lobes. The ovary is exserted on a straight pedicel. No further evidence is required to prove that the plant is specifically distinct from *E. fasciculata* Thunb. (Fig. 2.).

Compare Fig. 3 with Fig. 4, which is the type specimen of *E. Schoenlandii* Pax. There can be little doubt that the two figures represent the same species, which is specifically distinct from *E. fasciculata* Thunb. Since the two species are distinct, the name *E. Schoenlandii* Pax cannot be regarded as a synonym of *E. fasciculata* Thunb. and, as *E. Schoenlandii* Pax is the oldest valid name applied to the plant, the name must be resuscitated.

E. fasciculata Thunb. and *E. Schoenlandii* Pax are only recorded from the Districts of Clanwilliam and Van Rhynsdorp. The figures reproduced represent somewhat juvenile plants, and the limits of variation of the adult plants have not yet been fully investigated.

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GENETICAL STUDIES OF *CARICA PAPAYA* L*
(abbreviated)

BY

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Read 8 July, 1938.

In this paper a simple hypothesis is presented on the determination of the three sex types commonly found in *Carica papaya*, popularly known as the papaw. These sex types are:—male (staminate), female (pistillate), hermaphrodite (bisexual). Staminate plants occasionally bear a few fruit, and bisexual plants show considerable variation in the type of flower produced, while the pistillate plant is stable. The Goodness of Fit Method (Fisher, 1932) was used for the statistical analysis of the ratios and the methods proposed by Immer (1930) for the determination of linkage values.

The Determination of Sex.

There are 9 chromosomes in the haploid condition in the papaya but no hetero-chromosomes were observed in this plant by Lindsay (1930).

In Table I the results are reported of the crossing of the different sex types:—

Table I.—Crosses between different sex types of the papaya. The letters P, S, H respectively stand for pistillate, staminate and hermaphrodite.

Cross	Segregation			Approximate Ratio		
	P	S	H	P	S	H
P x S ...	3654	3898	—	1	1	—
S (selfed)	38	129	—	1	3	—
P x H ...	754	—	762	1	—	1
H (selfed)	118	—	265	1	—	2
H x S ...	23	32	33	1	1	1

* A complete account on this together with a discussion on sex types and sex reversal will be published as a Science Bulletin of the Department of Agriculture of the Union of South Africa.

From the above results it can be concluded that both staminate and bisexual plants are heterogamous; that bisexual trees can only produce staminate trees among their progeny when crossed with staminate trees and not when they are either selfed or crossed with pistillate trees; that, similarly, staminate trees can only produce bisexual trees among their progeny when crossed with bisexuals, and not when they are either selfed or crossed with pistillate plants; hence the staminate plant does not carry a factor for bisexualism or the bisexual plant a factor for maleness, in the sense applied here; that since no true breeding staminate or bisexual trees have been found these types are permanently heterozygous. Storey (1937) has expressed similar views on the heterozygosity of these types.

The results of Table 1 may be explained, tentatively, on a factorial basis by assuming that maleness is determined by M_1, femaleness by m, and bisexualism by M_2, and that these factors are allelomorphic. Hence the genetic constitution of these types will be: staminate, M_1m; pistillate, mm; and bisexual M_2m.

Now in the crosses reported in Table 1:

$$mm \times M_1m = 1\ M_1m : 1\ mm$$
$$M_1m \times M_1m = 1\ M_1M_1 : 2\ M_1m : 1\ mm$$
$$mm \times M_2m = 1\ M_2m : 1\ mm$$
$$M_2m \times M_2m = 1\ M_2M_2 : 2\ M_2m : 1\ mm$$
$$M_2m \times M_1m = 1\ M_2M_1 : 1\ M_2m : 1\ M_1m : 1\ mm$$

With reference to the progeny of selfed staminate plants (Table 1) a 3 : 1 ratio was observed whereas the author expected a 2 : 1 ratio. Lack of space does not warrant a discussion on this point. It suffices to say that Storey's (1937) results confirm the view that the ratio should be 2 : 1.

From the above it can be assumed that M_1M_1, M_2M_2 and M_2M_1 are apparently not viable.

LINKAGE STUDIES.

Yellow, Y, flower colour is dominant over white, y, flower colour. In Table 2 linkage studies are presented of Y, y in relation to the sex factors M_1, M_2 and m. In Table 2 the M of the MY and My columns may either stand for M_1 or M_2 depending on the cross studied; the reader is requested to make the necessary substitution.

TABLE 2: A study of backcross progenies involving sex types and flower colour.

	Cross	Segregation				Recombination		P value for 1:1:1:1 Ratio
		M Y	M y	m Y	m y	No.	Per Cent.	
A	$\frac{m\,y}{m\,y} \times \frac{M_1Y}{m\,y}$	251	116	87	213	203	30·4±1·2	<·01
	$\frac{m\,y}{m\,y} \times \frac{M_2y}{m\,Y}$	63	107	103	68	131	38·4±1·8	<·01
B	$\frac{m\,Y}{m\,y} \times \frac{M_1y}{m\,y}$	75	58	59	66	—	—	±·50
	$\frac{m\,Y}{m\,y} \times \frac{M_2y}{m\,y}$	84	87	65	85	—	—	±·30

In the cross $\frac{m\,y}{m\,y} \times \frac{M_1Y}{m\,y}$ the P value for a 1:1:1:1 ratio of the segregating classes, is less than ·01 indicating that flower colour and sex are not inherited independently. The analysis of the data indicates a linkage of 30·4 ± 1·2 per cent. in the coupling phase, between sex and flower colour. Similarly in the cross $\frac{m\,y}{m\,y} \times \frac{M_2y}{m\,Y}$ bisexualism (M_2) shows a linkage of 38·4 ± 1.8 per cent. in the repulsion phase with flower colour. If M_1, M_2 and m are allelomorphic a perfect agreement between these linkage values should be expected. It has been shown, however, that even in repeated tests of known genes in maize (Emerson, et al. 1935) their linkage values do not show perfect agreement. Many factors which cannot be enumerated here are responsible for this. In the case of these papaya crosses difficulties incurred in the classification for flower colour as also poor germination of the seed are thought to be additional contributing factors.

In the reciprocal crosses for flower colour, listed in Table 2B no linkages were observed, as would be expected. This gives further support to the factorial basis of sex determination.

The cross $\frac{M_2y}{m\,y} \times \frac{M_1Y}{m\,y}$ may be treated as a backcross for the flower colour genes Y. y and the sex factors M_1, M_2, m (see Table 3, A. and B.) The linkages observed were 18·5 ± 5·04 per cent. between the factors M_1, m, and Y, y, and 22·2 ± 6·6 per cent. between M_2 and y (M_2M_1 individuals not appearing).

The difference between these linkage values is 3·7 ± 8.3 per cent., which not being significant, gives further support to the assumption that M_1, M_2 and m are allemorphic.

TABLE 3: Linkage studies of M_1, M_2, m with Y, y, in the cross $\frac{M_2 y}{m\ y} \times \frac{M_1 Y}{m\ y}$ A—Progenies produced by the fertilization of M_2y egg-cells with M_1Y, M_1y, m Y, and m y pollen.

B—Progenies produced by the fertilization of m y egg-cells with M_1Y, M_1y, m Y, and m y pollen.

	Genotypes				*Unclassified		Recombination	
A	M_2M_1Yy	M_2M_1yy	M_2mYy	M_2myy	M_2M_1	M_2m	No.	Per Cent.
	—	—	4	14	—	5	4	22·2±6·6
B	M_1mYy	M_1myy	mmYy	mmyy	M_1m	mm	No.	Per Cent.
	15	4	1	7	3	9	5	18·5±5·04

* Refers to plants which were too immature to classify them for flower colour.

INHERITANCE OF PURPLE VS. NON-PURPLE STEM.

Purple, P, stem colour is dominant over non-purple, p, stem colour. In Table 4 where backcrosses are listed involving stem colour and sex, good fits to 1 : 1 : 1 : 1 ratios are obtained, which indicates that there is no linkage between M_1, M_2, m and P, p.

TABLE 4: Backcross progenies involving the factors M_1, M_2, m in various combinations with P, p.

Cross	Segregation				P value for 1:1:1:1 Ratio
	M P	M p	m P	m p	
m m p p x M_2m P p	24	36	33	26	±·30
m m P p x M_2m p p	27	28	28	32	±·90
m m P p x M_1m p p	27	25	25	23	±·95

INHERITANCE OF YELLOW VS. RED FRUIT FLESH.

Yellow fruit flesh is dominant over red fruit flesh, and the factor symbols R and r have been, respectively, assigned to

them. In the F_2 progeny of yellow and red-fleshed plants 44 had yellow flesh and 12 had red flesh, and the P value for a 3 : 1 ratio is $\pm$·50. In a backcross the distribution of these two classes was 22 individuals each. This suggests a simple mendelian inheritance. No linkage of colour of fruit flesh and sex was observed.

Summary and Conclusion.

The data presented suggest that sex determination in the papaya may be explained on a factorial basis. Alternative theories are possible but as the simple hypothesis suggested seems to fit the data, preference is given to it.

A linkage between M_1, M_2, m and the genes for flower colour Y, y is observed. The inheritance of purple, P, vs. non-purple, p, stem colour, and yellow, R, vs. red, r, fruit flesh is studied, and simple mendelian ratios are obtained in both cases. These stem and fruit characteristics are inherited independently from sex.

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STUDIES ON THE WATER RELATIONS OF GRASSES. II: CORRELATIONS BETWEEN SUGAR CONTENT AND DAILY VARIATIONS IN WATER CONTENT OF THE LEAVES OF *THEMEDA TRIANDRA* FORSK.

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Read 8 July, 1938.

Introduction.

Data on daily and seasonal variations in transpiration, water content, suction force, etc., of leaves of *Themeda triandra* were published by Mes and Ainslie in 1935. The most outstanding result of the experiments reported was that the difference between the daily maximum and minimum water content of the leaves varied strongly at certain times of the season.

The greatest difference in water content was found in November 1934 and in April and May 1935. From December 1934 to March 1935 the difference between maximum and minimum water content was much smaller in spite of a higher transpiration, higher temperature and lower atmospheric humidity during these months. In September and October the daily variations in water content were similar to those found between December and March. (Tables II, III and IV).

Apparently the stronger daily variation in water content in November and towards the end of the season cannot be explained by an increased water output. More likely the water intake by the roots during the middle of the day was not sufficient to maintain an even water balance at these particular periods during the season.

The suction force of the leaves may have been partly responsible for the intake of water by the roots. Although the method used for determining the suction force of the leaves as a whole was by no means accurate, there were indications that there might be some correlation between variations in the suction force and daily variations in the water content. The suction force of the leaves was always relatively low in the mornings, but it was found that in December 1934, January and March 1935,

small decreases in the water content during the day were accompanied by considerable increases in the suction force. Later this was found to be the same in September and October (Ainslie 1935). On the other hand in November 1934, April and May 1935, strong decreases in the water content during the day were accompanied by relatively small increases in the suction force.

The suction force, however, is not only regulated by changes in the water content, but also by changes in the concentration of substances present in the cell sap such as sugars, salts, organic acids, etc. It was therefore decided to determine the daily and seasonal variations in the sugar content of the leaves to find out whether any correlation between variations in sugar and water content existed.

The same plants of *Themeda triandra* Forsk. (grown in the University experimental plots) were used as in the previous experiments. The growth of the plants was not as vigorous as in 1934-1935 when they had just been transplanted. Dead leaves of the previous season had accumulated and seemed to check the new growth. The plants were therefore burnt towards the end of July 1936. The first experiments were carried out the following October. Simultaneously experiments were done with plants growing on a hill near Pretoria.

Methods.

For analysis representative samples of leaves (about 5 to 10 gram each) of a number of plants, of about the same vigour and development, were collected in stoppered flasks and weighed. The leaves were cut up into small pieces and dropped into boiling 80 per cent. alcohol with a little sodium carbonate. In this condition the leaves may be kept more or less indefinitely according to Lehmann (1931). Afterwards, two further extracts were made by boiling the leaves for four hours with 200 cc. 80 per cent. alcohol. After the alcohol had been distilled off and the chlorophyll precipitated with boiling water, glucose, fructose and sucrose were determined in the extract.

Several methods for clarifying the plant extracts, for determining the effect of other reducing substances and for the analysis of the sugars were tested.

Dibasic lead acetate as a clarifying agent (van der Plank 1936) was found to be unsatisfactory because the precipitate could not be removed completely. Henrici (1928) also found that "there is some element in the grass leaves which inhibits the complete precipitation of lead." In the method finally applied the extracts were clarified with aluminium hydroxyde and animal charcoal. The remaining effect of other reducing substances was determined after fermentation of the sugars in the extract. According to Yemm (1935) no sugars are adsorbed by the charcoal if less than 0·25 gram charcoal is used and if boiled for less than 5 minutes. Experiments with pure sugar solutions (glucose and fructose) gave similar results. According to Archbold (1938)

however, charcoal clarification offers the simplest method for *reducing sugar* determinations, but is unsuitable when *total sugars* are to be determined, because it is impossible to avoid adsorption of sucrose. In these experiments charcoal clarification, as carried out by Yemm (1935), was resorted to because clarification with dibasic lead acetate seemed unsatisfactory. This problem will be further investigated.

For the analysis of glucose and fructose the modified Hagedorn-Jensen or ferricyanide method was eventually chosen (Hanes 1929, Widdowson 1931). Sucrose was determined after hydrolysis with invertase, by the same method.

Although criticism may be levelled against the use of this method, it was found that in these experiments this method gave the most consistent results. For the present problem relative differences in sugar content were of more importance than the absolute sugar content. It was felt that the relative differences found are accurate enough to be presented. At the same time the investigation on the most suitable method for the analysis of sugars in grass leaves is being continued. According to Harding and Downs (1933): "Each sugar problem requires a reagent suited to the conditions" and this seems to be particularly true in the case of grass leaves.

When daily variations were determined samples were collected at two-hourly intervals between 9 a.m. and 5 p.m. On the other days only one sample was taken at about 11 a.m.

The methods for measuring transpiration, water content of the leaves and soil moisture were the same as before (Mes and Ainslie 1935). Atmospheric humidity and temperature, however, were measured with an Assmann's Psychrometer.

An error in the data presented in the latter publication should here be rectified. Our later results showed that a mistake must previously have been made in the calculations of the soil moisture content. Unfortunately the exact mistake cannot be traced at this late stage, but it seems possible that in calculating the soil moisture content, the weight of the glass jars in which the samples were collected was not subtracted from the fresh weight, but calculated as part of the water content. The figures tabulated are therefore too high, except in Table V (page 298), where the correct amount is given. Consequently these figures can only give an idea of the relative differences in moisture content. The absolute figures should vary between about 3 per cent. for the dry to about 16 per cent. for the moist soil.

The experiments reported below were carried out by the junior author, G. M. Bot, who hopes to publish at a later date, the detailed account of the most suitable method for the analysis of the sugar content of grass leaves, together with the data collected on the daily and seasonal variations in sugar content. In the present paper only the results which have a direct bearing on the problem, as set out in the introduction, will be discussed.

Experimental Results.

In general the results on transpiration and water content were similar to those found in 1934-1935, except that the transpiration in 1936-1937 was lower (maximum 4·38 per cent. of fresh weight per minute) and the water content higher. The difference between daily maximum and minimum water content was also less. This may be explained partly by the lower transpiration and partly by the fact that the first observation was taken at 9 a.m. instead of at 8 p.m.

Daily variations of the water and sugar content of the leaves was studied on the 30th October, 23rd November and 8th December, 1936, and on the 29th January, 25th February and 22nd March, 1937. In Table I only the maximum and minimum values are presented. In the case of the sugar content the average daily value calculated from the five two-hourly readings taken between 9 a.m. and 5 p.m. is also given.

It should be noted that on the 23rd November, 25th February and 22nd March the difference between the daily maximum and minimum water content was relatively high. At the same time the average daily sugar content and the daily maximum and minimum sugar content were relatively low. No correlation could be found between these facts and the atmospheric conditions or transpiration (not shown in Table). On the 23rd November, however, the haulms were beginning to form. They appeared a few inches above the leaves and the inflorescences were just beginning to develop. Probably the low sugar content at this stage was due to transportation of sugar from the leaves to the developing haulm and inflorescence. This possibility has also been suggested by Henrici (1928). She found that in Bechuanaland the amount of direct assimilates in *Themeda triandra* was never as high in the second rainy period of the season as in the first, regardless of favourable moisture conditions. She states: "The reason is in all probability the haulm formation which takes place on the highest scale in this period. It is probable that the sugars migrate directly to the place of their consumption, to the root crown, and that they are not condensed to starch, but transform to cellulose and hemicellulose as structural material for the haulms. It is characteristic that *Eragrostis* does not show a decrease in assimilates as it forms haulms the whole year round and never shows a very high amount of direct assimilates."

The decrease in sugar content on the 25th February and 22nd March was probably due to a gradual decline in the assimilation intensity and in the general vitality of the plant.

In general the trend in the difference between daily maximum and minimum water content corresponded to that reported before (Mes and Ainslie 1935). The only difference is that in 1935 there was a marked increase in the difference in water content from April onwards, whereas in 1937 this increase was already found

TABLE I.

Date	Temperature in °F.		Atmospheric Humidity in %		Water Content			Reducing Sugars and Sucrose in 1 mg. per gram fresh weight			
	Max.	Min.	Max.	Min.	Max. in % fresh weight	Min. in % fresh weight	Difference	Average Daily Value.	Max.	Min.	Difference between Max and Min
1936											
October 30th ...	80·3	66·6	55	12	62·14	59·95	2·19	7·81	11·10	5·28	5·82
November 23rd .	78·0	69·2	63	47	61·86	55·74	6·12	3·90	6·08	2·14	3·94
December 8th ...	85·0	83·0	44	19	56·30	52·82	3·48	5·36	9·92	2·66	7·26
1937											
January 29th ...	77·0	68·5	84	65	59·43	57·23	2·20	5·88	7·23	3·94	3·29
February 25th ...	78·5	70·5	55	44	65·23	57·89	7·34	3·36	4 84	1·94	2·90
March 22nd ..	89·0	76·0	71	17	58·16	50·84	7·32	2·12	2·70	1·17	1·53

at the end of February. In 1937, however, the grasses began to die off towards the end of March, whereas in 1935 they were still partly green at the end of May.

It seems likely that the greater difference between daily maximum and minimum water content observed on the 23rd and 29th November, 1934, also coincided with haulm formation. Unfortunately this was not recorded at the time.

The graphs of the daily variations in sugar content also showed a different behaviour at different times during the season which may be significant. On days when the greatest variations in water content were found there was a decrease in the sugar content from 9 a.m. to 11 a.m. This was followed by an increase at 1 p.m. and again by a decrease later on. Particularly on the 23rd November this last decrease was very marked. The result was that on those days not only a low minimum sugar content was found, but also a relatively small difference between maximum and minimum sugar content (see last column in Table I).

On the days when relatively small variations in water content occurred the daily variations in sugar content showed an almost opposite behaviour. There was an increase in sugar content between 9 a.m. and 11 a.m. followed by a decrease at 1 p.m. and again by a very strong increase in the late afternoon. Only on the 29th January was there a slight decrease in the sugar content between 3 p.m. and 5 p.m. The day, however, was cloudy and a little rain fell during the afternoon. This may possibly have affected the assimilation because even the starch content decreased between 3 p.m. and 5 p.m. In all other experiments, without exception, the starch content, when present, increased rapidly in the late afternoon. The maximum sugar content on the 29th January was therefore not as high as could have been expected from the relatively high minimum. The difference too, between maximum and minimum sugar content was less than expected. The relatively small variation in the daily water content, however, can still be explained by the relatively high minimum sugar content, and also by the general atmospheric conditions on that day.

The relatively low minimum sugar content on the 8th December was reflected in the slightly greater difference in the water content.

Finally, it may be pointed out that the smallest difference between maximum and minimum water content, namely 2·19 per cent. was found on the 30th October when the atmospheric humidity dropped to 12 per cent., but when the minimum, as well as the maximum sugar content, reached the highest values recorded during the season. In previous experiments it had also been found that the smallest variations in daily water content occurred in early spring (Mes and Ainslie 1935, Tables II, III and IV and Ainslie 1935), independent of atmospheric conditions or soil moisture, as within the limits observed.

It therefore seems that in every case the differences found between maximum and minimum water content at different times during the season, may be explained on the basis of the sugar content of the leaves at those particular periods. The sugar content will influence the suction force of the leaves and through this the water intake by the roots. In extreme cases, of course, the environment will also play a part in determining the water-balance of the plants. For instance under moist conditions a more even water-balance may be maintained not withstanding a low sugar content. On the other hand external and internal factors which increase the transpiration and decrease the water intake by the roots, may increase the difference between the daily maximum and minimum water content.

The next problem to be solved was whether the decrease in sugar content of the leaves found on the 21st November was actually due to the haulm formation.

In Table II data are presented of analyses of samples collected at 11 a.m. on the various days. These data are given because more days are represented than in Table I.

TABLE II.

Date	Temperature in F°	Atmospheric humidity in %	Reducing sugars + sucrose in mg. per gram fresh weight	Starch in mg. glucose per gram dry weight
October 21st, 1936 ...	75·9	41	8·12	—
October 30th, 1936 ...	72·3	55	8·19	1·71
November 9th, 1936	63·5	83	8·70	2·04
November 23rd, 1936	73·2	56	2·38	0·33
December 8th, 1936	85·0	34	5.06	0·98
January 29th, 1937...	74·5	70	6·06	2·49
February 12th, 1937	78·0	63	4·45	6·75
February 25th, 1937	76·0	47	1·94	0·48
March 10th, 1937 ...	84·0	32	1·26	0
March 22nd, 1937 ...	79·0	61	1·17	0

The results of the study of the daily variations showed that, when only one sample is taken at a particular time during the day, the results may be misleading. For instance, on some days there was an increase in sugar content at 11 a.m., whereas on other days a decrease was found at the time. If, however, the increase always occurs on days of relatively low sugar content,

as seems possible from the results obtained, the difference in sugar content will be accentuated by taking samples at 11 a.m. The figures are therefore interesting enough to be presented. The values found run more or less parallel to those obtained from the daily variations as given in Table 1.

In Table II figures for starch are also given in m.gr. glucose per gram dry weight. (Analysis carried out on material left after extraction of the sugars and after hydrolysis with taka-diastase). It will be noticed that the values for starch run more or less parallel with those for sugar content. The same drop in starch content, as in sugar content was found on the 23rd November when haulm formation became visible. The only difference is that the highest starch content was found on the 12th February and that from then onwards it dropped rapidly and disappeared in March.

The same experiment was repeated in the spring and early summer of 1937. Early rains fell in September and October and the plants showed new growth earlier than in the previous season. On the 4th November haulm formation was already visible. On that day the sugar content dropped to 0·99 m.gr. per gram fresh weight as compared to 7.30 m.gr. on the 30th October. Later in November the sugar content again increased. These results are similar to those obtained in the previous season and are therefore not presented in detail. The only difference is that the drop in sugar content and haulm formation occurred earlier in November probably due to climatic conditions.

Simultaneously similar analysis were carried out on samples of leaves of *Themeda triandra* collected at 11 a.m. on a hill near Pretoria. These grasses had also been burnt in August and the first green leaves appeared in September. Haulm formation was already visible on the 28th October. The results are given in Table III. In this table the moisture content of the soil is also included to show that there was no direct correlation between variations in the sugar content of the leaves and soil moisture.

The results of the analysis show that the drop in sugar content again appeared when haulm formation became visible. In this case as early as the 28th October. In these experiments the short grass stems which were about 0·25 to 1 inch in length were also analysed. The leaves and the adventitious roots which came out between the leaves were first removed. The figures in Table III show that a relatively high sugar content was found in the stems at the beginning of the new growth of the plants. This sugar may have been stored in the stems either in the form of sugar or of starch during the winter. It soon disappeared during the growth of the leaves, but suddenly appeared again and increased during haulm formation. Apparently at that time sugar was transported from the leaves into the stem and from there to the developing haulm and inflorescence. Unfortunately the very young inflorescences were not analysed on the 28th October. Analyses on the 12th November and 1st December

TABLE III.

Date	Temperature in F°	Atmospheric humidity in %	Soil moisture in % of fresh weight	Leaves: Reducing sugars + sucrose in mg. per gram fresh weight	Leaves: Starch in mg. glucose per gram dry weight	Stems: Reducing sugars + sucrose in mg. per gram fresh weight	Stems: Starch in mg. glucose per gram dry weight	Inflorescence: Reducing sugars + sucrose in mg. per gram fresh weight	Inflorescence: Starch in mg. glucose per gram dry weight
1937									
September 23rd ...	75·0	27·0	8·19	1·37	0	5·32	0	—	—
October 7th ...	71·4	67·4	15·5	4·87	0	0	0	—	—
October 15th ...	80.0	39·5	11·85	3·10	0	0	0	—	—
October 28th ...	74·0	52·5	9·34	0·54	0	9·79	0	—	—
November 12th ...	96·0	14·0	6·32	3·91	0	12 08	0	9·12	15·62
December 1st ...	73·0	55·0	3·49	2·75	6·23	9·60	0	11·41	17·43

however, show that sugar as well as starch were accumulating in the inflorescence. On the 1st December the seeds were not quite ripe yet.

Apparently however, the sugar content of the leaves was mainly affected by the first stages in the development of the haulm and inflorescence, because during the formation of the seeds, the sugar and starch content of the leaves again increased. It is also a known fact that the growth of plants stops during flowering and continues again during the development of the fruit (Went 1930).

The fact that starch was not present at 11 a.m. in the spring and early summer of 1937 in the leaves of the grasses grown in the plots, nor out in the veld, may have been partly due to climatic conditions. In October 1936 the rainfall was 1·44 inches, whereas in November 6·69 inches was recorded at the meteorological station in Pretoria. In 1937 after the early rains in September (0·71 inches and during first part of October 2·71 inches) no rain fell during the last week of October, and only 0·56 inches during the whole of November of which 0·44 inches fell on the 29th November. At the beginning of December, however, 1·90 inches of rain fell during the first week and starch was then again found in the leaves.

Another result worth mentioning is that the sugar content of the leaves of grasses growing on the experimental plots in sifted, fertilized soil, was higher than that of the leaves of grasses growing under natural conditions in the rocky, uncultivated soil on the hill near Pretoria. This fact becomes evident when comparing the figures in Table II and III. It should, however, be remembered that in Table II figures represent the results of a fairly wet season 1936-1937, whereas Table III contains the results of the first dry part of the season 1937-1938. Comparison of values obtained during the same season, however, showed the same results, although the differences were not as great.

A final experiment to prove the correlation between the drop in sugar content and the beginning of haulm formation was carried out at the beginning of November 1937. Leaves from two plants growing in the same experimental plot were analysed. The one plant showed no signs of haulm formation whereas in the other haulms were beginning to develop. In the first case 3·92 m. gr of sugar (reducing sugars plus sucrose) per gram fresh weight were found, and in the second case only 0·74 m.gr. This difference is large enough to be significant.

Conclusions and Discussions.

From the experimental results the following conclusions may be drawn.

At the beginning of the new growth season some sugar is present in the short stems of *Themeda triandra*. This sugar disappears during the early stages in the development of the new leaves. The sugar content in the leaves then increases and

reaches a relatively high value when the leaves are fairly well developed. This high sugar content ensures a fairly even water balance in the leaves. The highest sugar content and the smallest variation in daily water content were found at this time of the season and stage of development of the plants.

As soon as haulm formation starts, sugar is transported from the leaves to the stems and from there to the developing haulms. The sugar content of the leaves therefore decreases. This low sugar content which may be accentuated by a further decrease during the first part of the morning and again later in the day, influences the suction force of the leaves and indirectly therefore the intake of water by the roots. As a result this stage is accompanied by a strong increase in the difference between the daily maximum and minimum water content of the leaves. This variation in water content may be accentuated by other external and internal factors, which increase the water output, or decrease the water intake by the plants. On the other hand other factors which decrease the water output, or supply more favourable conditions for water intake, may lessen this difference.

The development of the seeds takes place relatively slowly in comparison with the first stages in the formation of the flowers and apparently does not make the same demands on the plants. The sugar content of the leaves therefore again increases during this stage. Simultaneously a more even water balance can be maintained and the difference between the daily maximum and minimum water content decreases.

In order to determine whether the decrease in sugar content is gradual and also just at what stage an increase in sugar content again takes place, it will be necessary to study the daily variations in sugar content at much shorter intervals before and after flowering.

Towards the end of the season, probably owing to a gradual decline in the activity of the plants, the sugar content of the leaves again decreases rapidly to a very low value and remains much more constant during the day. This low sugar content again influences the suction force of the leaves and indirectly the water intake by the roots. An even water balance can no longer be maintained during the day, and there is a strong increase in the difference between the daily maximum and minimum water content. The lowest sugar content and the greatest variation in daily water content is found at this time of the season.

Just when this stage will appear will depend on the rate of growth and the intensity of the various metabolistic processes in the plants during the whole of the season. This again will be determined by general climatic conditions prevailing during the season.

Summary.

1. Daily and seasonal variations in water and sugar content of leaves of *Themeda triandra*, Forsk., growing in the University experimental plots and on a hill near Pretoria, were determined.

2. The sugar content of the leaves was relatively high at the beginning of the season.

3. When the haulms and inflorescences began to develop, the sugar content suddenly decreased. At this stage the sugar was transported from the leaves to the stem and developing haulms.

4. During the formation of the seeds and also later in summer, the sugar content of the leaves increased.

5. Towards the end of the season the sugar content again decreased, due probably to a decrease in the assimilatory activity of the leaves.

6. The low sugar content found at certain stages in the growth of the plants influences the water intake by the roots. As a result low sugar content was correlated with an increase in the difference between the daily maximum and minimum water content.

7. Haulm formation was associated with a low sugar content of the leaves and a strong variation in the daily water content.

8. The lowest sugar content and strongest variation in daily water content were found towards the end of the season. The highest sugar content and smallest variation in daily water content were found at the beginning of the season.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 317-318, December, 1938.*

A COMPARATIVE STUDY OF THE OSMOTIC VALUES OF THE LEAF SAPS OF CERTAIN SOUTH AFRICAN HIGH-VELD GRASSES

BY

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Read 8 July, 1938.

ABSTRACT.

The study of the osmotic values in plants has interested many investigators from different points of view, particularly physiological and ecological. More recent work on the subject deals with the osmotic values and bound water content in relation to drought and frost resistance, and indicates that the latter is the more reliable index.

The purpose of the present investigation was to make a comparative study of the osmotic values of certain grasses from the same habitat, with regard to their seasonal fluctuation, range and correlation with soil moisture content. The pH value of the leaf saps and soil were also determined, using quin-hydrone and saturated calomel electrodes by means of a Cambridge hydrogen ion potentiometer.

The grasses selected were *Trachypogon plumosus*, Nees., *Elyonurus argenteus* Nees., and *Themeda triandra*, Forsk., and were collected from the Botanical Research Station at Frankenwald.

The osmotic values were determined by cryoscopic means, using a Beckmann thermometer. The grasses were gathered weekly at approximately the same time from the same region. In order to collect sufficient material, it was found necessary to gather the grasses over an area of approximately quarter of an acre.

Soil samples from a depth of 10 cms. were taken by means of a soil borer in the vicinity of each grass. Solid carbon dioxide was found to be the most satisfactory means of freezing the material and rendering the tissues permeable. The sap was expressed by means of an Amsler hydraulic press, using a pressure of 20 tons to the square inch (1 ton=2,240 lbs.). The extraction chamber was not removed until the pressure dropped to 3 tons.

After the sap was collected in test tubes, the samples were placed in ice until the freezing point depressions were made. At least 12·5 ccs. sap were necessary for these determinations.

Supercooling was recorded, and the true depression calculated from the observed depression, using Harris formula $\triangle = \triangle' - \cdot0125\,U\,\triangle'$ where $\triangle'$ denotes the observed freezing point and U the degrees of supercooling below $\triangle'$. The osmotic values were expressed in atmospheres, calculated from a theoretical value of 22·4 atmospheres for 1·86° depression. In each case the volume of expressed sap was noted, and calculated as a percentage of the fresh weight.

The results were recorded from 10th March, 1937, to 11th May, 1938, except for the winter months.

Results

(1) Results showed similarity in variation of the osmotic values during the period of investigation.

(2) The osmotic values for *Trachypogon plumosus* were lower than those of the other two species. while those of *Themeda triandra* were, in general, higher than those of *Elyonurus argenteus*.

(3) The range of osmotic values was greatest in Themeda and lowest in Trachypogon.

(4) The rate of change of the osmotic values in the three species was almost the same.

(5) The osmotic values appear to be characteristic of individual species.

(6) The seasonal trend showed low osmotic values in spring, gradual increase in summer and a rapid increase towards the end of the season.

(7) While there was a correlation in osmotic values and soil moisture, the relative increase and decrease was often quite disproportionate.

(8) Though there was no direct correlation between the percentage of sap yielded on expression and the osmotic values, in general, a greater percentage of sap indicated a lower osmotic value and vice versa.

(9) There was usually a larger percentage of sap expressed after rainfall, and a decrease at the end of the season.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, p. 319, December, 1938.*

STUDIES IN PASTURE MANAGEMENT

KIKUYU GRASS, ITS COMPOSITION AND RETURNS AS MEASURED BY MILK PRODUCTION

BY

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Read 8 July, 1938.

ABSTRACT.

Grazing Experiments on Kikuyu Grass (*Pennisetum clandestinum*) carried out at the School of Agriculture, Cedara, are described.

Two areas of Kikuyu pasture each of an acre in extent were selected and divided into three or four camps which were grazed in rotation, in one case by two Friesland cows and in the other by three Jerseys.

These pastures, originally established on good sites, were liberally fertilised with a mixed fertiliser in which nitrogen in the form of sulphate of ammonia predominated. Light dressings of agricultural lime were also given on alternate years.

The milk yields over a period of years are given, averaging approximately 1,000 gallons per acre during the growing season of seven months. This was at first entirely derived from grass but latterly a small ration of maize meal was given, 1½ lbs. to the Friesland Cows and 1 lb. to the Jerseys at each milking.

Data are given for the yield of herbage grazed over a period of three years, amounting approximately to four tons of dry matter per acre per annum.

The results of analysis indicate high protein and phosphoric oxide contents, often exceeding 25 per cent. and 1 per cent. respectively, based on the dry matter of the herbage as grazed.

From the economic standpoint the production of milk from such high grade intensively managed pastures is cheap and satisfactory.

South African Journal of Science, *Vol. XXXV, p. 320, December, 1938.*

SOME ASPECTS OF WATTLE PATHOLOGY

BY

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and

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Read 8 July, 1938.

Abstract.

The field of pathology covered in this paper includes diseases due not only directly to bacteria, fungi or viruses, but also to physiological upsets, resulting reaction from such causes as insect attacks or from undetermined causes.

The species of wattle dealt with are the *Acacia mollissima* Willd and the *Acacia decurrens* Willd. The cultivation of these species in South Africa is the basis of the Wattle Industry, the annual value of the products of which stands to-day at over 1¼ million pounds.

The diseases referred to and fully described in the paper are "Gummosis," the "Albert Falls" disease, collar-rot, Frog-hopper damage, etc., and have always been present in the industry, but it is only recently that they have assumed special significance. The reason for this is the change in cultural methods, involving thinning regimes which reduce the stocking per acre to 200 to 300 trees by the end of the second or third year.

Except for one publication in 1914, practically no work has as yet been done on in these diseases. The authors, therefore, in deciding on the lines of investigation first to be tackled have had to confine themselves to those lines which held out the greatest hopes of yielding practical and economic methods of control.

The lines of investigation adopted are those relating to the nutritional aspect of plant immunity to disease, with special reference to the role played by "trace elements."

Other lines of investigation will not be neglected, and will be tackled as and when time and opportunity offers.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 321-326, December, 1938.*

SUCCESSION OF TEETH IN SHARKS, *SELACHII*

BY

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With 1 Photograph.

Read 4 July, 1938.

Fish nibble their food under water, but mastication is impossible. They swallow most of their foods whole. The circle of teeth which surrounds the mouth is adapted for catching hold of slippery surfaces.

The exposed teeth of sharks can sever the stoutest lines and nets and readily cut through human flesh and bone. If embedded in sockets like human teeth, they would be snapped off. Their teeth have been found injured by metal or spines, but those submitted to most use are as well serrated as unerupted teeth. Others which at first sight appear to be worn down are, on closer examination, seen to be poorly developed.

Sharks' teeth are not found in aquariums, where they would occur if constantly shed under natural conditions, but many, which have resisted disintegration after the rest of the fish has been devoured, are found on the ocean bed.

Measuring of individual teeth shows that the largest are directed downwards and out of obvious use. The majority of those best formed are covered by the gum. The pulp persists until the shark is full grown so that the teeth continue to grow after eruption. An average-sized shark may possess teeth an inch in height, but teeth five inches across have been reported.

Whilst attacking a whale, the " Blue Pointer " has been said to elevate two or three rows of teeth which usually lie recumbent; this prehensile movement of the gum may be observed after sharks have been caught.

Some jaws of the Ragged-toothed shark, *Carcharias taurus*, suggest that the central buffer of both jaws meet when the mouth closes, and that the sword-like teeth overlap and interlock when food is severed, but no grooving of the teeth has been observed, nor is there evidence that the opposing teeth actually meet. Serration of the teeth of other species renders overlapping unlikely, and supports the idea of a sawing action of the teeth.

Prominent toothed sharks sometimes lose teeth through contact with the planking of boats, but there is little evidence of teeth missing from other causes during the life of a shark.

To their prey, the circle of exposed teeth may resemble coral, and their array of complex and formidable teeth is not a true indication of ferocity. Some species which have little use for strong teeth are provided with a better supply than some hunting species.

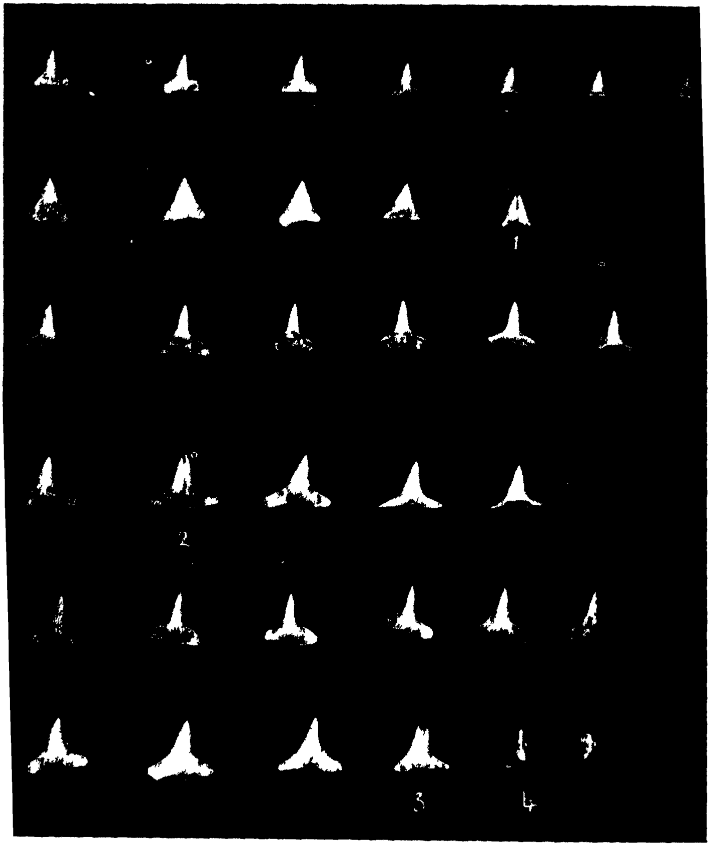

Photo. L. Acutt, Durban.

Photograph of complete rows of *Carcharhinus*, two species, to show relative length of the teeth of horizontal rows, splitting of teeth at 1, 2, 3 and 4 and the persistent pulp of posteriad teeth.

We cannot explain why the jaw of a shark contains so many teeth. The dentition is a complete entity which has not been

created for use. Louis Roule (1935: 119) states "There is no such thing as creation by use, nor making perfect by using, nor the dwindling of a structure as a consequence of function. Nature never ceases to produce something new. Then, from all these novelties, life makes a choice and makes the best possible use of them for diversive functions."

In the living state the gum containing the teeth slides over the jaw. The joint at the angle of the jaw suggests some side-to-side movement of the teeth as well as antero-posterior movements. Prehensile movement safeguards the teeth against mechanical stress. Slight protrusion brings the foremost teeth into an erect position. Increased movement raises the teeth immediately behind them.

As previously observed (Radcliffe: 1916) the number of teeth varied in different individuals of the same species I examined, and in various parts of the same jaw, indicating that opposing teeth do not overlap. It was exceptional to find teeth out-of-line except in the exposed row, all lying in parallel rows in different degrees of recumbency. An individual tooth in any row almost always lies exactly in line with the corresponding teeth of adjacent rows.

Individual teeth were easily removed after soaking the gum. By carefully removing the gum I counted the rows of teeth in many jaws. If, as is alleged, sharks are polyphyodont, teeth in all stages of development should be ready to replace those shed from the exposed rows. The tooth germs of *Elasmobranchii* are distinguishable from the surrounding gum only in the early stages. In mature jaws I found the hindermost rows of teeth incomplete but larger than those of younger specimens, many of these showed degeneration of the enamel.

In some examples of *Carcharias taurus* the anterior teeth of the hindermost rows were markedly overcrowded and degenerate, indicating that they represented the vestigial remains of useless structures.

Development of new teeth in the hindermost rows did not correspond with loss from the foremost portion of a vertical row. In some portions of the jaw a vertical row might contain two or three more teeth than in other parts of the same jaw, and an extra tooth was sometimes seen in front of the exposed row without indication that adjacent teeth had been shed.

Since Andre (1784: 280) attempted to prove succession of teeth in sharks, few cases have been reported where abnormal teeth are attributed to injury sustained during the life of a shark. In these cases the split teeth all lie in the same vertical row, and there is no adequate reason for assuming that they represent newly-formed teeth.

Careful study of Andre's (1784) illustration of the jaw of *Galeocerdo tigrinus* shows two vertical rows of stunted teeth, the

left row being identical with the left half of normal teeth and the right identical with the right half of normal teeth. Separation of the two halves would account for an increased width of from 2 to 4 mm., but the height of each tooth is approximately that of the normal teeth of the jaw. Whilst dissecting some of the jaws I inadvertently split several teeth which thus came to resemble those described by Andre.

In the jaw of *Carcharhinus limbatus* described by E. W. Gudger (1937: 267) a vertical row of divided teeth likewise corresponds to normal teeth which have been divided as a result of injury, rather than representing teeth which have been formed subsequent to an injury.

Such injuries as are caused by harpoons and spines penetrate the jaw and necessarily render the gum adherent to the cartilage. This hinders any possible shedding of teeth from a continuous, forward movement of the gum, as is supposed. Of this arrested movement there is no evidence in these injured specimens.

However, in a jaw of *Carcharhinus melanopterus* belonging to A. Anderson of Durban, there is a damaged tooth apparently driven back from the front row and fixed to the tooth immediately behind it.

Most bony fish renew their worn-out teeth at the site where one is lost. The reserve teeth of sharks are all directed backward as though having some other purpose than that of the exposed teeth.

Professor Thomas Barbour of the Museum of Comparative Zoology at Harvard University says:

"Personally I do not believe, and never have believed, that the dentition of a shark is not a permanent entity. I do not believe that replacement occurs, do not see how it could do so unless a whole row were replaced at once."

The backward direction of sharks' unerupted teeth resembles that of reptiles, and it is probable that they may exert some action through the gum in retaining the severed food, but the hindermost can have little such use.

There is a close analogy in the pavement teeth of rays which are more subject to abnormal variation, being fixed and used for crushing molluscs. Abnormal lines in their jaws have been attributed (Gudger 1933: 64) to the back teeth replacing those shed anteriorly, but at all stages of development the front teeth appear to be ground smooth from use, thus giving a false impression of erosion.

It would be difficult to prove that shedding and replacement ever occurs in gill teeth (Payne 1938: 401).

There is a gradual increase in size of the teeth of all sharks' jaws from the angle of the jaw, but there has never been any thought that the front teeth are replaced by hinder teeth of the same transverse row.

Barnacles attached to the front row of teeth in a living example of *Carcharias taurus*, caught by B. Maritz at Hibberdene, indicated that the outermost teeth of both jaws seldom meet, and that the front row is largely out of use. The upper jaw contained 19 teeth on each side. The lower contained 19 on one side and 18 on the other in each transverse row.

A jaw of the Bule Pointer, caught by C. R. Blamey at Hibberdene, weighing 233 lbs., possessed typical teeth, as shown in the measurement of corresponding teeth of vertical rows:

Row	Upper Jaw		Lower Jaw	
Exposed	11 mm.	12 mm.	18 mm.	17 mm.
Second	16 mm.	18 mm	18 mm.	17 mm.
Third	16 mm.	18 mm.	18 mm.	17 mm.
Fourth	16 mm.	17 mm.	17 mm.	17 mm.
Fifth	15 mm.	18 mm.	16 mm.	17 mm.
Sixth	13 mm.	15 mm.	16 mm.	16 mm.
Seventh	9 mm.	13 mm.	8 mm.	12 mm.

A specimen of *Carcharias taurus* of his, weighing 368 lbs., had 19 teeth in each transverse row of the right side of the Upper Jaw and 20 on the left. It had 19 teeth in each transverse row of the right side of the Lower Jaw and 18 on the left. A barnacle, 1/32in. high and 3/32in. wide was attached to the side of one exposed tooth of the lower jaw, about its centre and on the inner side. There were seven rows of teeth in upper and lower jaw.

CONCLUSIONS.

Examination of available records fails to reveal conclusive evidence of stunted teeth being formed as a result of injury. The divided teeth recorded correspond with teeth split during extraction.

Exposed teeth are well serrated even after prolonged use, and shedding of teeth would seem to occur only from exceptional injury such as may occur during capture.

The theory of succession rests on unsound evidence, and other explanations are needed to account for unerupted teeth, which are backwardly directed and may assist in directing the food down the throat, like the teeth of reptiles.

Little attention has been directed to the normal dentition of sharks at various ages, or to abnormalities in their jaws.

Measurement of the teeth from vertical rows indicates that the number of teeth remains fairly constant throughout the life of a shark, that those with which a specimen is born remain in the jaw throughout its life, gradually increasing in size, even if recumbent and out-of-use.

The hindermost and least-used teeth become degenerate and the hindermost rows are usually incomplete at all ages.

Teeth formed subsequent to an injury would be arranged in a mushroom-like form around the site of the injury, the gum being permanently attached to the cartilage of the jaw.

If reserve teeth were intended solely for replacing erupted ones which are shed they would not be directed backwards. The hindermost teeth are of little use and do not come into play however long the shark lives.

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THE PRINCIPLES OF THE CHROMOSOMAL BASIS OF SEX DIFFERENTIATION WITH SPECIAL REFERENCE TO *DROSOPHILA MELANOGASTER*

BY

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Johannesburg.

Read 4 July, 1938.

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BLOOD CYTOLOGY OF THE TORTOISE *TESTUDO GEOMETRICA*

BY

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(From the Department of Anatomy, University of the Witwatersrand).

With 1 Text Fig.

Read 4 July, 1938.

A study of the available literature reveals but scanty information as to " normal " standards for tortoise blood from the haematological aspect, nor is there any accurate description of the cellular elements.

This investigation comprised observations on 15 adult laboratory animals of the species *Testudo geometrica.* The haematological results have been presented in tabular form (Tables I and II).

1. CYTOLOGY.

Red Blood Cells. (Fig. 1).

Four successive forms in maturation are present in the circulating blood.

(i) *Early Erythroblast* (2)—A large cell with a central large nucleus, showing a homogeneous light blue nucleoplasm. The cytoplasm stains in a remarkable manner. One pole of the cell is distinctly basophilic, while the opposite end takes up eosin faintly, demonstrating the presence of haemoglobin. In supravital preparations (Janus green B and neutral red in saline solution) the cytoplasm shows the presence of numerous mitochondria and neutral-red stainable bodies.

(ii) *Late Erythroblast.*—This cell has the same general characteristic as the early erythroblast, but represents a later stage in maturation. Haemoglobin is more abundant as is shown by the deeper eosin stain of the cytoplasm and the absence of basophilia. Coincident with the increase in haemoglobin content, both the mitochondria and neutral red stainable bodies are less numerous.

The nucleus shows the beginnings of a chromatic network, large chromatic masses of a slightly denser hue being distinguishable in the nucleoplasm.

(iii) *Normoblast* (5)—This is the representative red cell of the tortoise; it is an oval flat disc with a central bulging about the nucleus. The cytoplasm has a homogeneous appearance with

TABLE I.

HAEMATOLOGY OF THE TORTOISE, *TESTUDO GEOMETRICA*.

	Red cells per ccm.	Hb per 100 ccs.	Differential Red Cell count: 200 cells counted					Coagulation time in Mins.
			Early Erythroblast %	Late Erythroblast %	Normoblast %	Erythroplastid %	Nuclear Element %	
Mean ...	642,000	8.0	6·2	8·2	82·0	1·6	2·0	4·13

	White cells per ccm.	Differential White Cell count · 100 cells counted						
		Neutrophils %	Eosinophils %	Basophils %	Lymphocytes %	Monocytes %	Thrombocytes %	Macrocytes %
Mean ...	45,487	·3	10·8	8	56·1	9·4	12·8	2·6

TABLE II.
AVERAGE DIMENSIONS: 100 CELLS MEASURED.

	Cell. microns.	Nucleus. microns.
Red Blood Cells:		
Early Erythroblast	25 x 18	10 x 10
Late Erythroblast	20 x 18	10 x 10
Normoblast	18 x 10	8 x 4
Erythroplastid	16 x 10	7 x 4
Nuclear Element	——	5 x 5
White Blood Cells:		
Neutrophil	18 x 16	——
Eosinophil	22 x 20	5 x 6
Basophil	15 x 15	10 x 10
Lymphocyte	7 x 7	6 x 6
Monocyte	15 x 30	10 x 10
Thrombocyte	6 x 8	4 x 4
Multinuclear	20 x 50	——
Macrocyte	20 x 40	12 x 20

Romanowsky and haematoxylin stains, and the affinity of the cytoplasm for eosin is greater than in the erythroblastic stage, due to the increasing percentage of haemoglobin.

The nucleus is central and oblong, and the nuclear structure contains large dense chromatic granules, some 10-25 in number, suspended in a nucleoplasm taking a lighter stain.

A still later stage in maturation is seen showing the presence of eccentric nuclei, extrusion of nulcei (17) and fragmentation of nuclei resulting in the following forms:

(iv) *Erythroplastid* (7)—This is a non-nucleated red blood cell. The occurrence of such cells in the blood of vertebrates other than mammals is now accepted as normal. It shows a cytoplasmic reticulation with brilliant cresyl blue.

(v) *Nuclear Element* (15)—This includes those bodies extruded in the formation of the erythroplastid, and the nuclei from the disintegrated normoblasts. These elements take a dense black-purple stain with Romanowsky stains, and the chromatic granules stain brilliantly with alcoholic solutions of neutral red and brilliant cresyl blue. By such methods nuclear elements can be clearly differentiated from thrombocytes and lymphocytes, which are similar in form.

White Blood Cells.

The white cells fall into two groups, the granulocytes and the non-granulocytes.

(a) *Granulocytes.*

(i) *Neutrophil*—The neutrophil is an extremely occasional cell, only twelve having been seen in the course of the investigation. The cytoplasm is finely granular, deep lilac in colour, and shows the presence of large vacuoles and crystalloid inclusions.

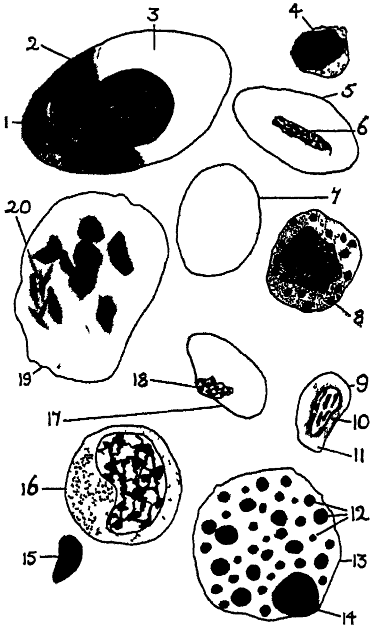

Figure 1: TORTOISE BLOOD.
Blood film stained with Leishman's stain.

1. Basophilic pole.
2. Early Erythroblast.
3. Eosinophilic pole.
4. Lymphocyte.
5. Normoblast.
6. Elongate pycnotic nucleus.
7. Erythroplastid.
8. Basophil.
9. Thrombocyte.
10. Pink cytoplasm.
11. Blue cytoplasm.
12. Bright pink granules.
13. Eosinophil.
14. Eccentric pycnotic nucleus.
15. Nuclear element.
16. Monocyte.
17. Late normoblast.
18. Extrusion of nucleus.
19. Multinuclear.
20. Crystalloid inclusions.

(ii) *Eosinophil* (13)—The eosinophil forms a conspicuous feature in blood smears and has been regarded as the " special white cell " of the tortoise. The nucleus is placed at one pole of the cell and is often obscured by the eosinophilic granules.

The cytoplasm is filled with coarse eosinophilic granules, and one may define three types of cells based on the colour reaction of the granules to eosin, namely, bright pink, dull red and purple-red.

(iii) *Basophil* (8)—The nucleus is centrally placed, stains a pale blue, and tends to be obscured by the large basophil granules in the cytoplasm.

(b) *Non-granulocytes.*

(i) *Lymphocyte* (4)—The lymphocyte has a dense black-purple nucleus surrounded by a thin rim of granular, dark blue

cytoplasm with an amoeboid outline. By means of supravital stains, a few scattered mitochondria and neutral red stainable bodies are seen in the cytoplasm.

(ii) *Monocyte* (16)—In general, monocytes show an abundant, slightly basophilic cytoplasm, accumulated to one side of a kidney-shaped nucleus with a fine reticular network. Stained supravitally, a clump of neutral red stainable bodies is seen to occupy the cytoplasm within the indentation of the nucleus, surrounded by numerous blue-green mitochondrial rodlets.

(iii) *Thrombocyte* (9, 19)—These are small cells, and have a tendency to clump into groups (multinuclear element), and to lose their cytoplasm leading to a nuclear element.

(iv) *Macrocyte.*—These cells are the largest of the leucocytic elements. The cytoplasm is a light grey colour and is finely granular and filled with vacuoles. The nucleus is large and excentric; it has a light grey-blue appearance and a delicate chromatic network.

2. Discussion.

The low red cell count and haemoglobin content, resulting in a low blood oxygen content, is in harmony with the low energy requirements of this cold-blooded vertebrate.

The granulocytes of the tortoise present many interesting features. The finding of cells neutrophilic in appearance would appear to confirm Alder and Huber's report that neutrophils are present in tortoise blood (1923). The fact that three types of eosinophil may be distinguished based on the reaction of the cellular granules to Romanowsky stains is in accord with Eberhardt's (1909), Werzberg's (1911) and later workers' recognition that these represent progressive stages in the life-history of the cell. Both Michels (1923) and Jordan and Speidel (1929) maintain that the basophil is a young eosinophil, and hence these three classes of eosinophils would represent so many stages in maturation. Additional evidence is the immature appearance of the basophil nucleus and the mature pycnotic nucleus of the "true" eosinophil. It would suggest that the ultimate stage in maturation of the tortoise granulocyte is the eosinophil.

3. Acknowledgments.

I am indebted to Prof. R. A. Dart for the facilities enabling me to carry out this work, and to Dr. J. Gillman and Dr. H. B. Stein for their interest and advice throughout the investigation.

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THE RELATION OF MITES TO ANIMALS AND PLANTS IN SOUTH AFRICA

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Read 5 July, 1938.

The order Acari, as usually understood by zoologists, is taken to include the leathery-skinned ticks from which the mites, as they are treated in this paper, differ in their smaller size and soft integument. The Ixodides or ticks are definitely excluded from the scope of this paper for the reason that they have already been adequately dealt with by numerous workers, and that furthermore their relation to animals in South Africa has been ably summarised by the late Mr. G. A. H. Bedford in his extremely useful check-list of South African external parasites. Though, however, this work contains lists of mites which are of great economic interest, these are confined to parasites of vertebrate hosts, and do not include the large numbers which parasitise, or are found in association with, invertebrates. This observation refers especially to mites affecting insects and to those which are injurious to plants.

The mites, as distinguished from the ticks, are as poorly known as the latter group is well known. The order is an extraordinarily large, difficult, and diverse one, and its taxonomy has not yet crystallized into clear-cut and stable forms. Even upon the boundaries of such large divisions as families and suborders systematists are still unable to pronounce with unanimity.

Nevertheless the writer considers that something is to be gained from a general review of the mites occurring in South Africa, even though it performs only a temporary service. Lists of parasites and their hosts can always be checked, added to, and revised. It is especially hoped that such a general list may form a rough guide to economic entomologists who are continually finding these parasites attached to the insects in their collections and are at a loss to give them any other label than the vague definition of " mite."

Vermiformes.

1. *Family Demodicidae.*—Vermiform mites with 3-jointed legs, living in the skin of mammals. One genus, *Demodex*, is found on cats, dogs, goats, and pigs *Demodex folliculorum* lives

in the sebaceous glands of man and is a very common parasite, being found in the skins of a large proportion of the human race. The mite does not usually give rise to any skin disease, and owing to this fact and to its minute size, is not noticed unless specially looked for.

2. *Family Eriophyidae.*—The family consists of extremely small worm-like mites and is closely allied to the previous family, the Demodicidae. They are strictly plant feeders and many of them are gall formers; others by sucking the juices of plants cause wilting and falling of the leaves. They make up for their extremely minute size by their great numbers. *Eriophyes* has been found on cedar pines, oaks, sugar cane, and other trees and cultivated plants. Another species seems to be confined to tomato plants, and the pear tree blister mite, *E. pyri*, has been brought into South Africa from other countries. *Phytoptus vitis* causes erinose of the vine, a disease characterised by blister-like swellings of the leaves.

SARCOPTIFORMES.

3. *Family Listrophoridae.*—Small mites living in the fur of mammals with either the fore or the hindlegs modified to form a clinging device for attachment to a hair. *Labidocarpus* is found on the nasal vibrissae of the leaf-nosed bat, *Rhinolophus*, and has recently been recorded from South Africa by the writer (12), *Listrophorus* in the fur of rabbits, *Campylochirus* and *Myocoptes* in the fur of guinea-pigs and rats respectively.

4. *Family Tyroglyphidae.*—Minute soft-bodied mites of considerable economic importance, only a few being parasitic on other animals. *Tyroglyphus* is found in cheese, copra, vanilla and many cereals, sometimes causing an itch (" grocers' itch ") in the hands of persons handling these commodities. *Carpoglyphus anonymus* has been detected by the writer in raw sugar in Natal; in Europe it has been found floating on the surface of sweet wines, and on dried figs, dates, prunes, etc., which have been left lying for some time in warehouses. *Rhizoglyphus* attacks the tubers of vegetables and plants such as onions, potatoes, tulips, dahlias and hyacinths and in this way has been spread over the greater part of the world.

The following genera have been noted as either attacking insects or found associated with them, *Trichotarsus* on the wings of a large wasp, "*Hypopus* " under the wing-covers of a beetle, *Anoetus* on a bee (*Koptorthosoma*), *Glyciphagus* in the nest of the same bee, *Sennertia* on the large carpenter bee (*Xylocopa*), *Myrmoglyphus* on the ant, *Dorylus fulvus*. *Tyroglyphus* has also been found attacking the pupae of a Buprestid beetle at Cape Town (6).

5. *Family Cytoleichidae.*—A small family allied to the Sarcoptid (Mange) mites, the legs and mouthparts being much reduced. These mites usually bore into the skin and encyst.

The single genus found in South Africa, *Cytoleichus*, attacks the common fowl, being usually found in the air passages and air cells, where its presence in sufficient numbers may produce asphyxia. A single case has been recorded of this parasite attacking man, a specimen having been found in the skin of a West African negro (7).

6. *Family Tarsonemidae.*—A small family but of much biological and economic interest. These are soft-bodied mites differing from all other Acari in possessing a prominent hair-like clavate organ between legs 1 and 2, which is of uncertain use. The posterior legs are far removed from the anterior pairs. The abdomen in the female of *Pediculoides* when distended with eggs becomes many times the size of the rest of the body. The mites of this family are predaceous and also seem to act as scavengers. In all probability they attack any form of invertebrate of suitable size. *Pediculoides* is found all over the world and has been known to attack the pupae and adults of a Curculionid, *Hoplitopales lineatus*, and a Buprestid, *Sphenoptera cupreosplendens*, both beetles living near Cape Town (6). *Tarsonemoides* and *Imparipes* have been captured in association with the termite *Termes natalensis*, the latter genus having being also recorded from a Forficulid. *Tarsonemella* has been taken on *Alfonsiella* at Mossel Bay. *Locustacarus*, according to Ewing (5) lives in the air sacs of the migratory locust *Locusta migratoria*. *Podapolipus* has been found beneath the elytra of the beetle *Pimelia*. *Acarapis* enters the tracheal passages of the honey bee and by blocking them causes the "Isle of Wight disease," while *Tarsonemus*, though not injurious to the health of the honey bee, uses its host for purposes of transportation (8) A species of the last named genus has been recorded on man taken from cancerous tissues, into which it was probably introduced accidentally.

7. *Family Analgesidae.*—This family consists entirely of the feather-mites, all its members living in the feathers of birds. Most of the genera live in the barbules of the feathers, a few entering the quill itself. Other genera live on the skin of the bird while a few burrow beneath its surface. In many genera the legs of the first, second, or third pair are much enlarged. About 37 genera and nearly a hundred species have been recorded from birds in South Africa. Two genera, *Epidermoptes* and *Rivoltasia*, which live on the surface of the skin, have been accused of causing a squamous skin disease in the common fowl.

8. *Family Sarcoptidae.*—The itch mites. These are small round-bodied mites with greatly reduced legs ending in a bristle or sucker. Tracheal tubes are absent. The members of this family burrow into the skin of man and other mammals, producing intense itching and a diseased condition known as scabies, mange, or acariasis.

Sarcoptes, the common mange-mite, is found on man, dogs, cattle, goats, horses, sheep, rabbits and pigs. It has also been found on the following South African wild animals: Koodoo, hartebeest, blue wildebeest, steenbuck, silver jackal, and a captive lion in Europe (2).

Psoroptes is responsible for Psoroptic mange or scab and is found usually in the ears of cattle, rabbits, horses, and sheep.

Otodectes. The mites of this genus live in the ears of dogs and cats. It is a very common parasite of London cats and the form of otitis caused by it is usually known as Canker.

Chorioptes causes symbiotic mange which occurs on goats in South Africa and other domestic animals in Europe.

Notoedrus gives rise to noteodric mange which in the case of rabbits attacks the face, especially round the eyes. Cats, dogs and rats are also affected by it in South Africa.

Cnemidocoptes is the mite present in depluming itch of poultry. The following genera are parasites of other than domestic animals in South Africa: *Nycteridocoptes* burrows in the tissues of the ears of bats, and *Teinocoptes* lives on the same host. *Coleopterophagus* attacks a Cetoniid beetle, while *Myialges* is parasitic on the pupae of certain Diptera.

TROMBIDIFORMES.

9. *Family Cheletidae*.—This family consists of minute soft-bodied mites in which the palpi are usually large. All of them are carnivorous, some being predaceous, others strictly parasitic. *Cheyletiella parasitivorax* is found in rabbits' fur where it hunts a member of another family of mites, *Listrophorus*. *Syringophilus*, *Cheletoides* and *Cheletopsis* live in the quills of the feathers of birds, *Sarcopterinus* in the follicles of the feathers of pigeons, giving rise to cysts in the skin. *Myobia* lives in the fur of the house mouse, the first pair of legs being stouter than the others and transformed into an organ for grasping the hair. *Psorergates* is found in little cysts beneath the skin of the house mouse. *Anystis* is free-living and predaceous, feeding on *Collembola*, *Thrips* and other soft-bodied insects. *Cheletophyes* has been found in the nest of the large bee, *Koptorthosoma*.

10. *Family Pterygosomidae*.—The family is a small one entirely parasitic on lizards. The body is almost always broader than long and covered with symmetrically arranged hairs forming distinctive patterns.

Geckobia is found only on the Geckos; *Zonurobia*, *Scaphothrix*, and *Ixodiderma* on Zonurid lizards; *Pterygosoma* on the "spiny kogelmander" *Agama*, and the *Gerrhosaurus* . lizard. *Ixodiderma* is a large mite with a leathery skin resembling that of the ticks. All these mites are attached beneath the scales of the lizards, where they pass the whole of their lives. They are presumably blood-suckers (9. 10, 11).

11. *Family Tetranychidae.*—A small family whose members, however, are very injurious to cultivated plants. Commonly known as "red spiders" or spinning mites, since many of the species can spin a silken thread, these mites have needle-like mouthparts for piercing and sucking the juices of plants.

Tenuipalpus and *Anychus* attack citrus trees, *Oligonychus* is found on tea plants, while *Phytoptipalpus* lives in small galls on the bark of Acacia trees. *Tetranychus bimaculatus* the common red spider, is extremely abundant in most parts of South Africa, attacking plum and peach trees, beans, tomatoes, cotton, sweetpeas, and the Cape gooseberry. A related species *T. opuntiae* is very injurious to the prickly pear cactus in Texas. *Bryobia* sucks the juices of the leaves of pear and plum trees. Two genera of a closely allied family, the Eupodidae, have also been known to occur in South Africa, *Stereotydeus* and *Tydeus*, the latter being found on citrus fruit trees.

12. *Family Trombidiidae.*—This is one of the largest families of mites of economic importance. Most of them are large species and on account of their conspicuous red colour and velvety appearance have been called "velvet mites." The adults of these mites are all actively predaceous, living freely in the open or hidden under stones or bark of trees, but the larvae are very largely parasitic, attacking man and almost all vertebrates, as well as a large number of invertebrates. In Europe *Leptus autumnalis*, the harvest mite, is a larval form of *Microtrombidium* which fixes itself to human beings, giving rise to great irritation, sometimes accompanied by a severe rash and high temperature. In the Orient an allied form, *Microtrombidium akamushi*, carries the River fever of Japan to man with a high incident mortality; during its larval stage it is found in the ears of field mice. Human beings are not attacked by larval Trombidiids in South Africa but some mammals, many birds and reptiles, a few amphibians, and large numbers of insects and Arachnids are parasitised. Almost nothing is known about these mites as vectors of disease but it is not improbable that many of them actually harbour pathological organisms and transport them in the same way that some ticks are known to do. On the other hand many larval Trombidiids doubtless employ this method of attachment to other animals as a means of effecting a wider distribution. A few genera live commensally with other invertebrates, such as termites. *Trombidium* is found on Cercopithecus monkeys and on a bird (*Ardea*); *Typhlotrombidium*, *Leeuwenhoekia*, and *Microtrombidium* have been taken from bats, *Trombicula* from a cuckoo, and *Phanalophus* from the nasal cavities of lizards. Larvae of *Erythraeus*, *Microtrombidium*, *Fessonia*, *Rhyncolophus*, and probably other allied genera, occur in large numbers on South African lizards, Arachnida and insects. *Endotrombicula* and *Schongastia* have been taken on frogs, the latter genus also occurring on the domestic fowl in America. Species of *Speleorchestes* and

Rhyncolophus have been found in the nests of termites, *Pimeliaphilus* under the elytra of a beetle, *Pimelia*, while *Eutrombidium* attaches itself to Muscid flies.

PARASITIFORMES.

13. *Family Gamasidae*.—This large family of mites is allied to the ticks, and its members, though much smaller in size, have like them a hard body-covering. They have a well developed breathing system rather like that of the Ixodidae. Though most of the family are free-living, many are true parasites, attaching themselves to various animals and sucking their blood, while others apparently only attach themselves to insects for purposes of transport; a good example of such an insect "carrier" is the large female carpenter bee, *Xylocopa*, which carries a number of mites of the genus *Dinogamasus* in a little pocket at the anterior extremity of its abdomen. It is, however, doubtful if the mites ever leave their tolerant host. Some again live in the debris of the sleeping places or nests of small mammals. A few of the Gamasidae have become true internal parasites, such as *Pneumonyssus* in the lungs of the rock rabbit and the baboon, *Halarachne* in the bronchi of seals, and *Sternostomum* and *Rhinonyssus* which are found in the nasal cavities of birds, where they may cause suffocation of the host if occurring in large numbers. *Entonyssus* lives in the lungs of American snakes but probably also occurs in South African ones. Nearly 40 genera of Gamasidae are found in South Africa on various mammals, lizards, birds, centipedes, millipedes, flies, bees, ants, beetles and termites. The names of these are given in the host lists to be found in a later section of this paper. Very few Gamasid mites have been found on snakes, though an undescribed and probably new genus has been found embedded in the skins of two snakes, *Lamprophis* and *Boodon*, in the Western Province. None of these mites attack man, although in buildings invaded by *Dermanyssus gallinae*, a parasite proper to pigeons and the domestic fowl, the bites of the mite may constitute a temporary nuisance. Such a case was brought to the notice of the writer in 1930 when members of the municipal staff working in the City Hall at Cape Town were bitten on the hands and arms by large numbers of these mites coming down the walls from pigeons nesting on the roof.

A LIST OF SOUTH AFRICAN ANIMALS AND PLANTS PARASITISED BY MITES.

In this list only the genus or genera of mites living on any particular animal or plant is given. More than one species of mite is sometimes found in a given genus so that the list is a general, not a detailed one. Mites living commensally with, or attached to other animals for transport, are included in the list.

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REACTIONS OF BABOONS DURING FEEDING

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Read 7 July, 1938.

The colony of baboons housed in the Anatomy Department has made possible the study of the behaviour of the baboons in captivity. The following is a resumé of the reactions of the baboon during feeding.

Baboons are vegetarians and under normal circumstances will avoid meat when fruit and vegetables are available. When receiving food after a long fast, the animal does not exercise any discrimination, but crams its mouth and cheek pouches with everything within reach. Only when the first hunger is appeased does the baboon choose its food, and then it will only eat the choicest morsels. The unattractive will be left until he is hungry again, and long before the next meal is due the cage will be bereft of food.

When baboons first arrive from the veldt they are extremely nervous of the attendants and cannot be coaxed to eat in the presence of human beings. Although they have had scarcely any food for several days they will starve rather than come any closer to the attendant than the furthermost corner of their cage. It is sometimes months before this fear can be overcome.

Male and female baboon eating together.

Male and female animals have occasionally been housed together, and two types of reactions have been observed during feeding.

(a) The female has been dominant and the male has been unable to obtain food under any circumstances.

(b) The male has been the dominant partner and the female has only been able to obtain food by manœuvring and distracting the male with her sex-appeal.

Two females eating together.

Two very tame females have occasionally been chained near each other outside their cages. Food has been placed within the reach of both, but only the most dominant animal has been able to obtain any. The other baboon will not attempt to fight for her share, but will vent her wrath on some other animal or person

who happens to be nearby. She will snatch scraps of food when possible, and bolt them very hurriedly, but these opportunities will be rare.

Adult female baboon and infant baboons eating together.

Mature female baboons adopt motherless young very readily. In this colony there have been a number of such instances, and the foster mothers have been extremely possessive and jealous, allowing nobody else to pay attention to their young. All this affection disappears dramatically when mealtime arrives. The adult seizes all the food and the infant cannot obtain any until the adult is satisfied. If food is put right into the mouth of the baby by the attendant, the adopted mother will force open its mouth and remove the food with her fingers. The baby will scarcely struggle, but seems to regard this procedure as part of its lot in life. The infants can usually get outside of their cages whilst still on the chain, and food is sometimes put outside for them, but if the adult sees this she will drag on the chain and pull the baby inside together with his food, which she will take from him.

In one case of this character the baby became so thin and starved that he had to be removed from maternal comforts.

Young baboons feeding together.

When newly captured young baboons are put in a cage together, one baboon will always become dominant and aggressive and seize all the food. It is only when there is an excess of food that the other members of the group are able to get a reasonable supply. The smallest animal is sometimes very unfortunate in his gains.

On one occasion a very tame male was housed with a female of similar age who had come straight from the veldt. For a long time the male took all the food that was going, and the female crouched in the background and ate what was left, but after a year or so the female lost her fear and became more tame, and whenever food is now offered she is well to the foreground and frequently a fight ensues. From observations on this and other similar cases it seems that when two young baboons of similar age are housed together and when they have become accustomed to their surroundings and each other, the distribution of food is fairly equable.

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FUNDAMENTAL HUMAN FACIAL TYPES IN AFRICA

BY

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Read 5 July, 1938.

The layman, without specific training in anthropological method, identifies unerringly outstanding examples of the principal types of human racial types, his usual guide being that of skin colouration. This was also the earliest scientific procedure followed by Linnaeus when he divided mankind into white, yellow and black races.

The limitations of so simple a classification are apparent when we consider the black peoples of the world and find them including on the one hand the woolly-capped but otherwise hairless Negro, and on the other hand the curly-haired and otherwise very hirsute Australian Aboriginal. Consequently, Huxley divided living mankind into four great groups: smooth-haired (Mongolian), wavy-haired (Caucasian), curly-haired (Australian) and woolly-haired (Negro) on the basis chiefly of divergences in hair structure.

Meantime, Retzius in Sweden had shown that fair-skinned people consistently differed from one another in that one group (now known as Alpine or Armenoid) was short and square of skull while the other was long and narrow, and that in this respect the square-headed or brachycephalic Caucasians were nearer to the brachycephalic Mongolians than to the dolichocephalic Caucasians.

Then Sergi in Italy pointed out how the dolichocephalic brown-skinned, brown-eyed and black-haired Mediterranean peoples of Southern Europe and Northern Africa diverged from the dolichocephalic white-skinned, blue-eyed and fair-haired Nordic peoples of North-Western Europe. Elliot Smith demonstrated that this Mediterranean type was that characteristic of the ancient and modern Egyptian population, and that it was spread from Spain to India; he therefore changed the name and called them the Brown race. In *Human History* (1930) he has summarised our general knowledge of human races.

In this way, the " white " race of Linnaeus has become divided into Alpine, Nordic and Brown races, and some (cf., Stibbe, *Introduction to Physical Anthropology*. n.ed., 1938)

manufacture even further "Dinaric" and "Armenoid" varieties of the Alpine stock and an "Oriental" variety of the Brown race. Whether these subdivisions are genetically justifiable, further investigation can alone show. We know that all the races of mankind are fertile when crossed, hence there is no such thing as distinct species of mankind, there are merely divergent varieties. Certain of these racial subdivisions may, however, not even be true varieties but merely hybrids formed by the crossing of the genuine varieties represented by the Alpine, Nordic and Brown types.

For the last fifteen years we have been occupied in tracking down the human varieties that have contributed towards forming the living peoples of Southern Africa. Following up the preliminary work done by early travellers and collectors, we have made a standard collection of Bantu skeletal material. We have also made a collection of face masks from living and from dead subjects, which includes specimens ranging from Arabia through Central Africa to the Cape. Recently we have had the opportunity of correlating field observations with facial masks taken from family groups of Bushmen in the Kalahari, and of supplementing that study with knowledge accruing from repeated examinations by a large number of observers of osteological remains coming from every province in the Union as well as from Rhodesia and Tanganyika.

We therefore feel that we are now in a position to make a statement about the fundamental facial types, which, while still necessarily preliminary in character, can assist in the further conduct of racial analyses in Africa. Our concepts so far have been corroborated only to a limited extent by genetic study; but even for such human genetic studies, the maximum of preliminary agreement is required relative to the racial types being sought.

Curiously enough, while European anthropologists have recognised at least three "Caucasian" types they seem to recognise only one African or Negro type. Sergi believed Africa to be the ancestral home of the Mediterranean race. Elliot Smith, although recognising its widespread dispersal and renaming the race Brown, placed its homeland in the Abyssinian quarter of the African Continent. But in the southern two-thirds of the Continent, there are at least three distinct types of human face and head. Thus, if Africa is the homeland of the Brown race, it has given birth to at least four of the living races of mankind. They are tentatively described as follows:—

1.—Brown (or Mediterranean) Race.

These are peoples of medium height and slender (hyposthenic) in build, verging on the effeminate or juvenile in bony structure and bodily physique. Their glabrous, brunette bodies (15-19 on Von Luschan's scale) have scanty facial hair except for the eyebrows, a small moustache and a chin tuft; but their heads are richly covered with glossy, jet-black almost straight hair. The

iris is brown owing to a considerable retention of body pigment, but the conjunctiva is white. The skull is long (180-190 + mm.), relatively narrow (dolichocephalic), of relatively moderate height (orthocephalic), smoothly (obtusely) pentagonoid when viewed from above, and of moderate capacity (mesocephalic). The eyebrow ridges are poorly developed, but the fairly broad forehead rises erect and full above them, and the occiput is bulged out behind into a prominence. The orbits are horizontal, ellipsoidal and have thin margins. The cheeks are narrow and their bony supports flattened laterally; the mouth is well behind the tip of the nose. The small jaws and comely teeth do not project, and the chin is pointed. The face as a whole is straight in profile (orthognathous), relatively short, of moderate width and ovid in outline as seen from the front. The Brown racial type—in Frassetto's terminology—is a *juvenile* human type as compared with the *adult* Nordic and Armenoid types.

2.—Bush (or Pygmy) Race.

These are people of pygmy stature and of moderate (hyposthenic to sthenic) build; they are small-boned and child-like in bony structure and bodily physique. Their virtually hairless, deep copper-brown bodies (22-23 on Von Luschan's scale) are almost devoid of facial hairs save for the slight eyebrows; their heads, too, display relatively little hair, and what is present is in the form of little, tightly-rolled, black peppercorns discreetly scattered over the skull like a closely-fitting skull-cap. The iris is dark-brown and the conjunctiva dirty-white. The skull is short (170-180 mm.), relatively narrow (dolichomesaticephalic), relatively low (chamaecephalic), acutely pentagonoid when viewed from above and of small capacity (microcephalic). Eyebrow ridges are absent; the narrow forehead rises vertically or may even protude anteriorly and is bossed like that of a baby. The top of the head is flattened and slopes away to a prominent occipital boss. The orbits are crushed between the small forehead and face, they are quadrilateral in form being broader horizontally than vertically and tend to be tilted downwards in their lateral halves. The face is short and wide, and appears even more so because of the contrast between the prominence of the cheeks and the narrowness of the forehead and of the lower part of the face. Its breadth, however, is conspicuously less than that of the braincase. Thus the face is small in proportion to the braincase, retaining the proportions of infancy. The short, broad nose is flat and only slightly elevated beyond the profile of the inflated infra-orbital region of the face. Although the nose is so undeveloped or foetal in type, the oral region is not protruded beyond the nose. There is subnasal prognathism, but the mouth is small and not pursed and the lips are full but are shapely and not everted. The jaws are small, and the lower one is vertical in profile and sharply pointed. The small ears are square and non-lobulated. The face as a whole is almost straight in profile,

very short and wide, and smoothly pentagonoid in outline as seen from the front. The Bush racial type—in Frassetto's terminology—is a *foetal* human type as compared with the *juvenile* Brown or *adult* Nordic type.

3*—Boskop (or "Hottentot") Race.

These are the people of moderate structure (10mm. taller on the average than the Bush type) and sturdy (sthenic) in build, having a very robust bony structure and bodily physique. Their dark reddish-brown bodies (25-27 on Von Luschan's scale) are also virtually hairless save for the poorly-developed eyebrows and some straggly facial hairs; their heads are covered with large, coarse and scattered, black peppercorns, distributed like a skull-cap with a frontal prolongation. The iris is black-brown and the conjunctiva brownish-white. The skull is very long (190-200 + mm.), relatively narrow (dolichocephalic), relatively low (chamaecephalic) and acutely pentagonoid (trigonocephalic) when viewed from above and of great capacity (macrocephalic). Eyebrow ridges are present and distinct but not usually salient; the narrow forehead is bossed, and rises but in a slightly retreating fashion to the long and flat calvaria, which slopes posteriorly to a very prominent occipital boss. The orbits are horizontal, quadrangular and are ruggedly built. The cheeks appear prominent owing to the narrowness of the anterior part of the calvaria and give the face a rugged outline. The nose is broad and fairly long and slightly elevated, so that it appears funnel-like. Despite this and the fullness (but not inflation) of the infraorbital region, the jaws are so massive that the convex oral region is protruded and juts muzzle-like beyond the nose in profile. Owing to the general prognathism, the oral material appears as though inadequate to clothe the enlarged jaws; the mouth is large, wide and strongly pursed; the lips are wide, flaccid and transversely furrowed; and the massive lower jaw is receding in profile, thus emphasising the *chimpanzoid* (or muzzle-like) appearance of the lower half of the face. The long ears are pyriform but non-lobulated. The face as a whole is prognathous in profile, large and rugged, and pentagonoid in outline as seen from the front. The Boskop racial type—in Frassetto's terminology—is an *adult* human type as compared with *foetal* Bush and *juvenile* Brown types.

4.—Negro Race.

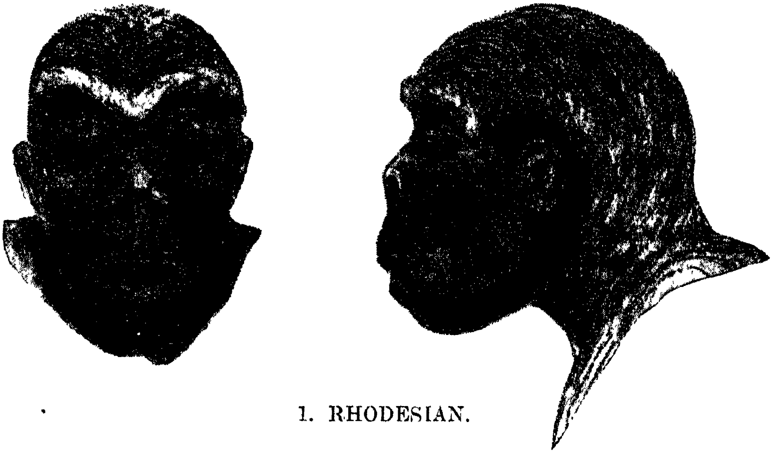
These are people of tall stature and robust (sthenic-hypersthenic) in build: they are large-boned and muscular in physique. Their bodies also are virtually hairless, and the skin is black (30-33 on Von Luschan's scale); the face, too, is practically hairless save for the eyebrows, but the head is covered with a

* The general physical, osteological and facial evidence upon which reliance has been placed for the description of this type has been treated more extensively in my paper on the physical characters of the /Auni=Khomani Bushmen. *Bantu Studies*, Sept., 1937.

dense, woolly mop of curled black hair. The iris is brownish-black and the conjunctiva pearly-white. The skull is long (180-190 mm.), relatively narrow (dolichocephalic) of relatively moderate height (orthocephalic), ovoid when viewed from above and of moderate capacity (mesocephalic). The eyebrow ridges are poorly developed or entirely absent, and the fairly broad forehead rises in rounded fashion to the vertex and runs with even curvature to the occiput, which is full and not bossed. The orbits are horizontal, quadrangular and strongly built. The cheeks are not unduly prominent owing to the width of the calvaria and the broad, lower jaw. The nose is fairly long and wide owing to the broad alae, and is moderately elevated beyond the profile of the full (but not inflated) supra-orbital region; its tip is usually projected and knob-like (giving a retroussé appearance or the effect of "flattening" of the bony portion). The jaws are strong and the face is prognathic, not only as regards the alveolar processes, but also the teeth. The oral region is full and muscular, the mouth broad and wide, the lips fleshy and elevated so that both lips are strongly concave in profile. The lower jaw does not recede, but has a broad triangular chin area, and is of considerable height and width lending a "quasi-Hapsburg" air to the Negro face. The prognathism of the face is such that the blunt chin lies vertically under the tip of the nose, and the lips project beyond the nose. The face as a whole is prognathic in profile, long and wide, rhomboid in outline as seen from in front. The Negro racial type—in Frassetto's terminology—is a *juvenile* human type as compared with the *foetal* Bush or *adult* Boskop type.

These four human racial types seem to form the principal stocks from which the living inhabitants of Central and Southern Africa are derived. When discussing racial origins in *The Bantu-Speaking Tribes of South Africa* (1937) I was under the impression that Australoid and Boskopoid types, although they cropped up in our living population, were "so numerically few and so sporadic in occurrence as to constitute anthropological curiosities." More recent investigation of the Southern Kalahari Bushmen has made me alter that opinion; for I found, contrary to expectation, that the Bushmen were a mixture in virtually *equivalent* parts of the Bush and Boskop stocks. Meantime, Wells and Orford have discovered a considerable Boskop element in their series of Bantu women. If, as I imagine, practically all Central and Southern African skulls giving a length in excess of 190 mm. are of the Boskop type, that race has left a considerable representation in our living population despite its extreme antiquity.

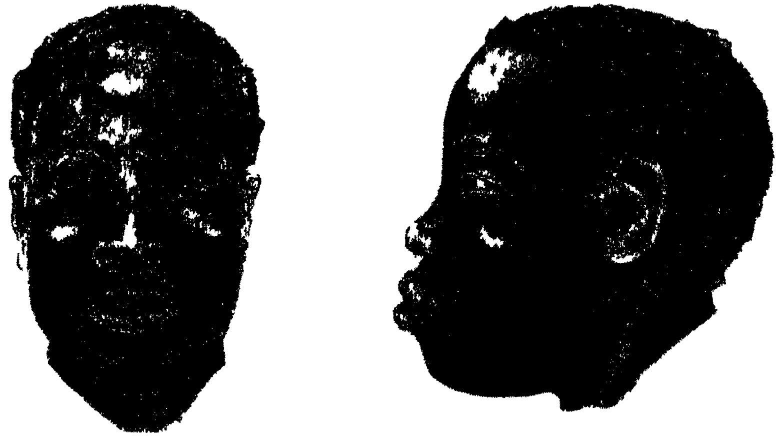
I am indebted for the drawings accompanying these notes to Dr. J. Penn, Lecturer in Clinical Anatomy at the University of the Witwatersrand. He has drawn them in consultation with Drs. Galloway and Wells and myself, and with the assistance of those skulls and facial masks which, after the analysis of the material, we regard as being typical of the several races.



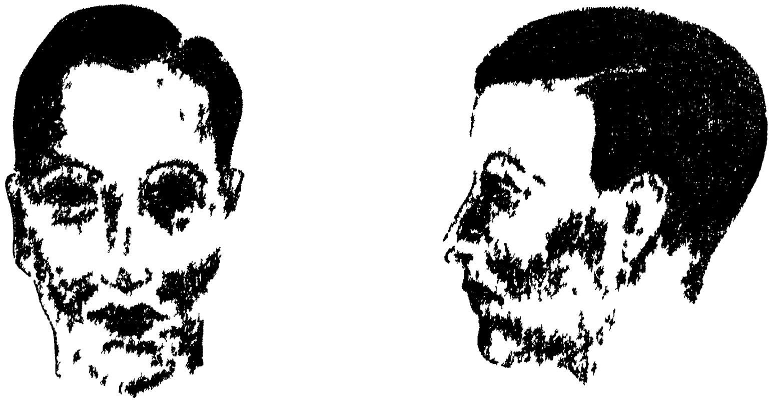
1. RHODESIAN.

2. BOSKOP.

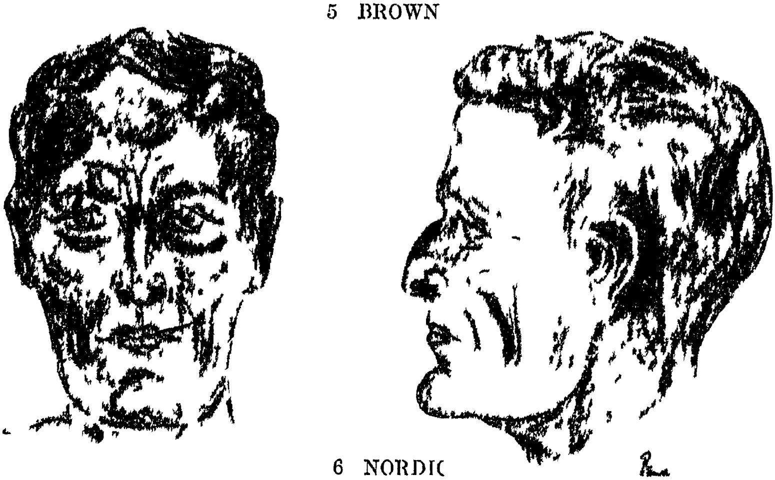
3. BUSH.



4 NEGRO



5 BROWN



6 NORDIC

For comparison with these, and in the light of the information gleaned as a result of these several exercises, Dr. Penn has also essayed a pictorial reconstruction of the face of the *Rhodesian race* drawn from a cast of that skull (cf. Elliot Smith *op cit.* Fig. 21.)

This type is distinguished by its extremely massive and virtually gorilloid eyebrow ridges, by an extremely retreating forehead, by a strong temporal musculature in the back of the neck. In the absence of the lower jaw, the nearest approach to that structure is the mandible of Heidelberg Man, which almost fits the Rhodesian skull: it was therefore used as a guide in modelling the lower part of the face. The architecture of the nasal region and upper jaw suggested the type of nose and oral region that has been sketched, and it is impossible to avoid the conclusion that although human, the face was even more muzzle-like or chimpanzoid than that of the Boskop race.

The Rhodesian face in large measure represents an exaggeration of the *adult* type seen in the face which we have ascribed to Boskop man. The latter, indeed, represents an attenuated form of the Rhodesian faces, in which the chimpanzoid features still survive in modified form.

Finally, for the sake of general comparison with all South African types, we have depicted the *adult* Nordic type. This, like all other reconstructions has been drawn to scale from the actual skull best illustrated of the type in our collection.

South African Journal of Science, *Vol. XXXV*, *pp. 349-360*, *December, 1938*.

FURTHER STUDIES ON THE HYOID BONE OF SOUTH AFRICAN RACES

BY

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Communicated by Dr. L. H. Wells.

With 6 Text Figures and 1 Table.

Read 5 July, 1938.

Introductory.

This is a brief report on certain features of the following five hyoid bones, acquired by our department since the publication of my account of the hyoid bones of Negro and Pre-negro South African races, viz.: A.D. 658, a hyoid bone of a man aged 50 years from the Southern Kalahari, just north of the Orange River, alleged to be a Bushman because he was a member of a Bushman tribe. The specimen consists of the body and the right greater cornu. The latter part is damaged at its free extremity. K. 21 (female, aged between 25 and 30 years) and K. 31 (male, aged between 21 and 25 years) were discovered in the Bambadyanalo skeletal deposit. (Galloway, 1938). Specimen K. 21 comprises the body and the disarticulated left greater cornu; K. 31 consists of the body of the hyoid bone only. U.N.M. 7, is the hyoid bone of an adult skeleton from Umgababa, Natal South Coast. Only the lesser cornua are missing from this well-preserved specimen. A.D. 382, a fairly complete bone except that the free extremities of the greater cornua are damaged, the right lesser cornu is absent and the tip of the left lesser cornu is destroyed, belonged to the skeleton of a male Bavenda, aged 29 years.

In order to compare the present specimens directly with those previously described, corresponding anatomical features will be considered in the same order. The metrical information is assembled in Table I. Projection contour diagrams are supplied in Figs. 1 to 6. In Figs. 1, 2, 5, and 6 the hyoids are orientated in such a way that the plane of the greatest height of the body is vertical to the horizontal. In Figs. 3 and 4 this plane corresponds to the horizontal.

Description.

1. *Anatomical Features.*

(a) *General Build of the Hyoid.*

A.D. 658 conforms more or less to the Bush hyoid, Type 1, is considerably smaller than the Mapungubwe type and appreciably less massive than the hyoid of the South African Negro. Its greater cornu tends to be large. In K. 21 and K. 31 the hyoid bodies are small but powerfully constructed. The greater cornu of K. 21 is also sturdily built, especially at its attachment to the body, and its general proportions are reminiscent of those of the Zitzikama Hyoid. U.N.M. 7 is uniformly massive like the South African Negro and Mapungubwe hyoids, but in its general proportions it resembles the Type 1 Bush hyoid. A.D. 382 is almost identical in size with the other South African Negro specimens, but its greater cornua are slenderer at their free extremities.

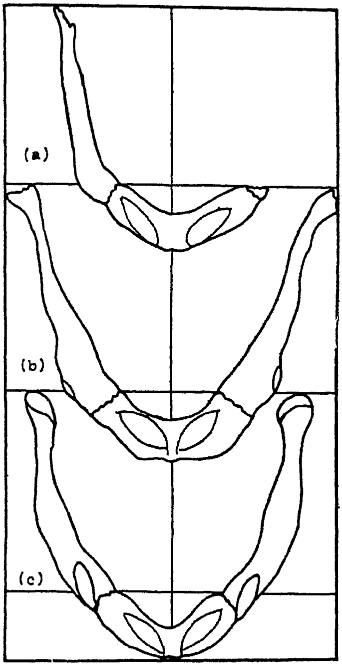

FIGURE 1.

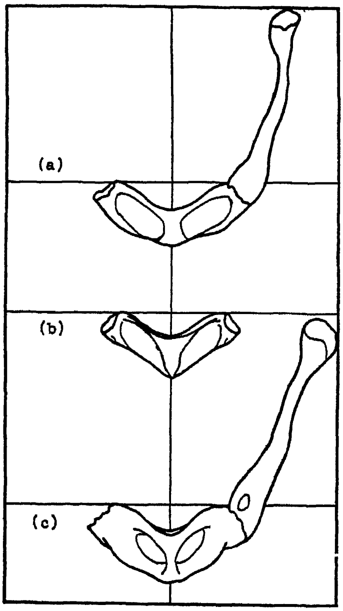

FIGURE 2.

(b) *The Body of the Hyoid*

In A.D. 658 the body is almost as well-developed as that of the Type 1 Bush hyoids. It is less convex transversely than that of the Mapungubwe specimen and is sharply convex forwards in the vertical direction. The anterior surface bears four

more or less smooth facets which form the sides of a large central pyramidal promontory of which the upper and lower sides are much more steeply sloped than the lateral ones. This is the first time such a projection has been recorded. The upper edge is at a lower level than the greater cornu and shows an even, uninterrupted, broad cavity. The sterno-hyoid flange is broad and projecting and is comparable to that of the South African Negro. Considerable thickening at the lateral corners of this flange is present as in Type 1 Bushman and Mapungubwe specimens.

The small elliptical genio-hyoid insertions are faintly indicated on the upper facet of the anterior surface. In depth they are intermediate between those of the Type 2 Bush hyoids and the South African Negro. Inclined at an obtuse angle to one another they face upward and forward. They are far apart. There is no central median ridge for the attachment of the mylo-hyoid raphe, as in the Type 2 Bush hyoids. Well-marked stylo-hydoid tubercles are present. The body is deeply concave posteriorly, as in Type 2 Bush hyoids.

K. 21 and K. 31. In the Bambadyanalo hyoids the features of the body are unlike those of the Negro and the Type 1 Bush hyoids, but in some respects they resemble the Zitzikama specimen. While some features of K. 21 also agree with those of the Mapungubwe specimen, K. 31 possesses anatomical peculiarities unlike any previously seen. Both hyoid bodies are relatively small. Sharply contrasted with these dimensions is their sturdiness of build. There is marked forward convexity in both their transverse and vertical axes. The concavity of the posterior surface is less in K. 21 than in K. 31. The upper edge is slightly concave in both. It is very sharp in its intermediate half and blunter laterally. In neither specimens can sterno-hyoid flanges be distinguished. The lower margins are evenly thickened throughout, as in the Zitzikama and Type 2 Bush specimens. Most distinctive features are present on the anterior surfaces of the two types. The nodularity of this surface in K. 21 resembles that of the Mapungubwe specimen. The ridges separating the genio-hyoid fossae from the shallower, smaller infero-lateral impressions are well-developed. The oval genio-hyoid impressions are very large and deep, inclined at a very obtuse angle to one another and face forward, upward and slightly laterally, and are only separated by a slight median ridge for the attachment of the mylo-hyoid raphe. The stylo-hyoid tubercles are poorly defined and elongated. In K. 31 the ridges below the genio-hyoid insertions are entirely absent. A prominent median ridge modifies the dorsal contour of the body considerably. The genio-hyoid impressions are very large and extend on to the anterior surface of the hyoid. The area for the attachment of the mylo-hyoid and its median raphe is extensive. No stylo-hyoid tubercles are present.

U.N.M. 7. The body of this hyoid is in all respects very large. Its shape is comparable to that of the Type 1 Bush hyoid. Its degree of transverse and vertical convexity is almost equal to that of the Mapungubwe hyoid. Its anterior surface is smooth like that of the South African Negro, and faces upwards and forwards like that of the Type 1 Bush hyoid. As in the South African Negro hyoid, the upper edge of the body is on a higher level than the proximal parts of the greater cornua. This margin, however, is blunt throughout, as in the Type 2 Bush hyoid. A conspicuous feature is the large sterno-hyoid flange composing the lower half of the body. It projects as much as that of the South African Negro but is much broader like that of Mapungubwe. The thickenings of the infero-lateral corners of the flange present in these types are less obvious in U.N.M. 7. Instead, a well-marked central, thickened, downward projection for the attachment of the thyreo-hyoid ligament, the intermediate half of the free edge of the flange is present, giving a contour which is an exaggeration of that present in the South African Negro. The areas of insertion of the genio-hyoid muscles are small, inconspicuous, elliptical impressions orientated at a very obtuse angle to one another. A slight tubercle is present between them being the only evidence of the site of attachment of the median mylo-hyoid raphe. Well-developed, slightly asymmetrically situated stylo-hyoid tubercles are present, as in the Type 2 Bush hyoid. The posterior surface of the body is smooth and only slightly less flattened than that of the Mapungubwe hyoid.

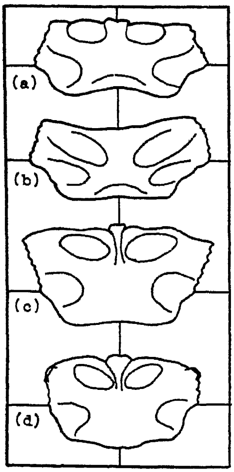

FIGURE 3.

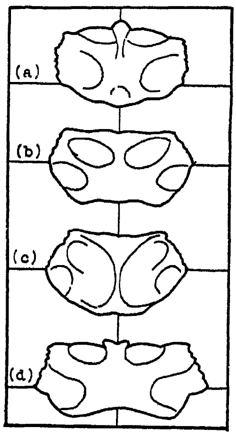

FIGURE 4.

A.D. 382. The majority of the anatomical features of the body of this specimen are typically Negro.

MEASUREMENTS (in millimetres). INDICES (as percentages).	A.D. 658. Male, aged 50 years. Alleged Bushman.
Maximal length of hyoid	34·0
Maximal breadth of hyoid	31·5
Breadth-Length Index of Hyoid	92·6
Length of greater cornua	29·0
Length of lesser cornua	—
Length of body	22·0
Length Index of body and greater cornua	76·0
Length Index of greater and lesser cornua	—
Index of length of body and maximal breadth of hyoid ...	70·0
Maximal height of body	11·0
Minimal height of body	6·5
Index of minimal and maximal heights of body	59·1
Index of maximal height and length of body	50·0
Maximal height of greater cornua	6·0
Minimal height of greater cornua	3·0
Index of Minimal and Maximal heights of greater cornua ...	50·0
Maximal thickness of body	4·2
Index of Maximal thickness and height of body	38·2
Maximal thickness of greater cornua	3·0
Minimal thickness of greater cornua	0·9
Index of maximal thickness and height of greater cornua ...	50·0
Index of minimal and maximal thickness of greater cornua	30·0
Greater cornu-body maximal thickness Index	71·5
Inclination of greater cornua to body	115·0°

d Bone Measurements and Indices.

K. 21. Female, aged 25-30 years. Bambadyanalo.	K. 31. Male, aged 21-25 years. Bambadyanalo.	U.N.M. 7. Sex? Adult. Umgababa.	A.D. 382. Male, aged 29 years. Bavenda.	Zitzikama hyoid.	Average Type 2 Bush hyoid.	Average Type 1 Bush hyoid.	Average South African Negro hyoid (Male).	M. 5. Sceptre Skeleton. Mapungubwe.
31·5	—	39·0	37·0	30·5	30·0	36·8	37·0	45·0
34·0	—	42·0	39·0	32·0	37·0	43·7	38·0	55·0
108·0	—	107·7	105·6	105·0	124·4	113·0	102·6	122·4
24·0	—	29·0	28·0	25·0	26·0	34·5	29·0	36·4
—	—	—	5·0	—	2·0	2·0	5·5	—
19·0	17·0	20·0	22·0	18·0	17·1	21·2	22·0	25·0
79·2	—	69·0	78·6	72·0	66·6	65·0	76·0	69·2
—	—	—	17·8	—	7·3	6·5	19·0	—
55·8	—	47·6	56·3	57·0	46·0	48·0	58·0	45·5
9·6	10·2	12·0	10·0	10·0	8·3	10·7	10·0	11·0
7·8	8·2	7·5	6·4	5·5	4·7	6·8	6·5	8·0
81.2	81·8	62·5	64·0	55·0	57·0	63·8	65·0	72·3
50·5	59·2	60·0	45·5	55·5	48·5	50·7	45·5	44·0
5·0	—	5·5	5·3	5·0	4·4	5·8	5·2	8·0
2·3	—	3·2	2·8	3·0	2·4	2·0	3·5	2·5
46·0	—	58·1	52·9	60·0	56·4	38·8	67·2	31·3
4·3	4·9	4·4	4·2	3·7	3·7	4·5	4·0	3·5
44·8	48·8	36·7	42·0	37·0	45·2	42·0	40·0	31·5
3·2	—	3·7	3·1	2·2	2·9	3·0	3·0	3·0
1·2	—	1·2	1·4	1·2	1·1	1·6	1·5	1·5
64·1	—	67·2	58·5	44·0	67·5	46·8	57·8	37·5
37·5	—	32·5	45·2	59·2	41·9	56·2	50·0	50·0
74·2	—	84·2	73·9	59·5	83·0	68·2	75·0	86·0
120·0°	—	105·0°	95·0°	70·0°	100·0°	85·0°	85·0°	90·0°

To face Page 352

(c) *The Lesser Cornua of the Hyoid.*

No clue remains to indicate where these were attached to the remainder of the hyoid in the first four specimens. This is not very extraordinary for K. 21 and K. 31 which belonged to relatively young individuals. In A.D. 658 and U.N.M. 7 some bone changes at the site of the articulation should, however, have been in evidence already, in view of the age of the individual. In A.D. 382 the left lesser cornu is attached to the body almost on the joint line, as is typical for the South African Negro. On the right side a small tubercle is present at this site.

(d) *The Greater Cornua of the Hyoid.*

A.D. 658. Though the free extremity of the greater cornu is damaged in this hyoid, it is clearly evident that it is singularly slenderly built throughout and relatively short as compared to the length of the body. Its frailness is due to its extreme mediolateral flattening. There is no longitudinal twisting of the part. In these respects the hyoid resembles the Zitzikama and South African Negro specimens, rather than the Bush hyoid. The greater cornu, moreover, is not straight and presents an upward concavity, when viewed laterally. Along the inferior edge only the thyreo-hyoid flange is present. The line of attachment of the investing layer of the cervical fascia is conspicuously marked above this flange. A further point of resemblance with the South African Negro hyoid is the reduction in height of the greater cornu just anteriorly to the thyreo-hyoid flange.

K. 21. An almost entirely different array of anatomical characters is present in the case of the greater cornu of the Bambadyanalo hyoid, K. 21. Its exact counterpart is not to be found amongst the hyoids so far examined. It has a considerable number of features in common, however, with the corresponding greater cornu in M.M.K. 174, one of the Type 2 Bush hyoids. Firstly it is relatively short as compared with the length of the body. Its absolute length is less than that of the Zitzikama specimen, but it is not so massively built as the latter and compares better with the Type 2 Bush hyoid in this respect. It agrees further with these types in that it is much thickened near its attachment to the body of the hyoid, and in that the remainder of the greater cornu becomes almost cylindrical, before expanding into the characteristic truncated termination of these hyoid types.

A feat which this greater cornu of K. 21 further shares with the Type 2 Bush hyoid is its orientation with reference to the body. The angle which its axis subtends with the vertical through the body is very obtuse. In addition the greater cornu is not straight, but has a marked upward curvature. This combination of features gives it the distinctive appearance depicted in Fig. 6 (b). But the Type 2 Bush hyoid differs from it in that

it has widely divergent greater cornua. All muscle markings are indistinct.

U.N.M. 7. The greater cornua in this specimen are in appearance very much like those of the South African Negro. But they are more massive, orientated more obliquely with reference to the body, their terminal expansions are larger and the thyreo-hyoid flange less developed than in the Negro. They are also slightly twisted on themselves along their longitudinal axes, as is the case in the Type 1 Bush hyoids. A.D. 382 the only variations from the typical Negro are: firstly, a more marked degree of longitudinal torsion than is customary and secondly a marked reduction in the height of the greater cornu met with as their free extremities are approached.

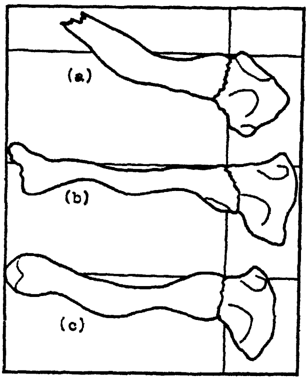

FIGURE 5.

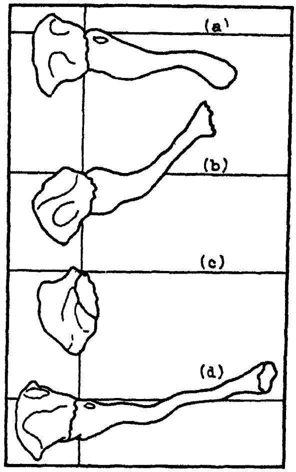

FIGURE 6.

(e) *Mode of Union of the Body, the Greater and the Lesser Cornua.*

A.D.658. Firm ankylosis had already occurred between the greater cornu and the body. On the left side the greater cornu had been detached by being fractured off through the joint line. Evidently, a true joint was present at first before bony fusion took place.

K. 21 and K. 31. True diarthrodral joints clearly existed also in the case of these hyoids, where the greater cornua were attached to the body. This is obvious from the considerable degree of eburnation present on the body in the case of K.31 and on the proximal extremity of the greater cornu in the case of K. 21. On the joint surfaces of the body of K. 21 some irregular bony deposits are present, as is quite in accordance with the greater age of the individual to whom it belonged. The joint surface of K 31 is very large and of semilunar shape, sug-

gesting a greater cornu with a greatly expanded proximal end and considerable flattening internally.

U.N.M. 7. In this specimen it is difficult to distinguish the joint line, which is distinct on the internal aspect only. A.D. 382. Here bony ankylosis at the greater cornu-body joints was attended with considerable formation of new bone. This firm union is rather unexpected in such a young individual. The left lesser cornu is likewise firmly attached by means of bone. On the right side osseus union of the lesser cornu with the body had not yet taken place. On both sides the original joint overlapped slightly on to the greater cornu-body joint line.

2. *Contours.*

(a) *Superior Aspect.* (Figs. 1 and 2.)

A.D. 658. The general shape is that of a **U** with slight divergence of the limbs. This is intermediate between the horse-shoe-shape of the South African Negro, and the **Y**-shaped dorsal contour of the Type 1 Bush hyoid. The relationship between the external and internal contours. is practically the same as in the South African Negro. Owing to the oblique orientation of the greater cornu it appears to be broad throughout when viewed from above. The thyreo-hyoid flange is inconspicuous. K. 21 and K. 31. In K. 21 the pattern of the dorsal contour is intermediate between a **Y** and a **U**, in that the limbs are almost straight and diverge slightly, while the apex is rounded. The greater cornua of K. 21 and the Mapungubwe hyoid are very similar. In the case of the bodies of both the Bambadyanalo hyoids less is visible of the structures of the anterior surface than in the Mapungubwe specimen. The features of the genio-hyoid impressions are well contrasted. It is scarcely necessary to indicate the central prominence on the anterior aspect of K. 31.

U.N.M. 7 and A.D. 382. These hyoids have not been included in the accompanying figures. The general shape of U.N.M. 7 viewed from above, is intermediate in appearance between that of the Type 1 Bush, and the South African Negro hyoid. The internal contour is a **Y** with a rounded apex. The external contour is almost **U**-shaped. This relationship is reminiscent of the condition in the Type 1 Bush hyoid. None of the anterior aspect of the body is seen if the bone is correctly orientated. A.D. 382 has almost typically Negro contours.

(b) *The Anterior Aspect.* (Figs. 3 and 4.)

A.D. 658. The shape of the body of A.D. 658 is roughly hexagonal, being remarkably like that of Mapungubwe with which it agrees further in regard to the shape of the sterno-hyoid flange. But the details of the pattern produced by the surface markings are, however, entirely different from those present on the Mapungubwe specimen.

K. 21. An even more simplified hexagonal pattern is recognised in the anterior surface of the body of the hyoid of K. 21 than that of the Mapungubwe hyoid. The large genio-hyoid impressions visible from the front further characterise this specimen. No median ridge is present either.

K. 31. In its shape K. 31 is pentagonal rather than hexagonal. Its upper half, with its slightly concave superior edge and sloping joint edges, agrees very closely with the corresponding part of K. 21. The lower margin is convex like that of the Zitzikama hyoid, but this region of the bone forms a considerably larger flange. K. 31 possesses a further characteristic feature in the distinctive pattern of markings present on its anterior aspect.

U.N.M. 7. In shape the body of this hyoid is a trapezoid, almost entirely like that of the Type 1 Bush hyoid. The sterno-hyoid flange, however, constitutes a slightly larger part of the body and the upper side is relatively broader. The median projection from the sterno-hyoid flange represents the attachment of the thyreo-hyoid ligament. Unlike in any other type, except the Type 1 Bush hyoid, the slope of the joint line is characteristically outward and upward. The upper margin does not show the slight upward convexity of the Type 1 Bush hyoid.

A.D. 382. The shape of the body of the South African Negro hyoid, when viewed from this aspect, was described as a broad rectangle. In this specimen, on account of the reduction of the sterno-hyoid flange, the body appears more elongated, though still remarkably rectangular in shape. In other respects the contours are like those already described for this type.

(c) *Lateral Aspect.* (Figs. 5 and 6.)

The margins of the greater cornu of A.D. 658 are on the whole less sinuous than those of the Bush and South African Negro. Its great upward curvature is similar to that of the Type 2 Bush hyoids. A.D. 658 also presents a marked upward angular curvature of its anterior margin, from this aspect. Herein it differs from the Bush or Negro hyoids; but the lateral aspects of the bodies of the Bambadyanalo hyoids are not unlike it. The greater cornua of U.N.M. 7 strongly resemble those of the South African Negro but are more sharply curved upward than in this type. The joint line is orientated like that of the Type 1 Bush hyoid. The shape of the body is like that of the Negro, less the central upward projection representing the ridge for the mylo-hyoid raphe.

A.D. 382 represents a few distinctive contour features, to which reference has not yet been made. But these may merely be variations of the Negro type.

3. *Metrical Features.*

A.D. 658. It is immediately evident that A.D. 658 is not identical in its size and proportions with any single other hyoid.

type. It possesses several features in common with each of the hyoids considered here, except the Mapungubwe specimen, with which it only agrees in regard to the maximal height of the body.

Certain measurements and indices are distinctive. Other metrical values correspond to those of the Zitzikama specimen. The bone is intermediate between the Bush hyoids, Types 1 and 2, in respect of the indices of the minimal and maximal heights of the body and the greater cornu respectively. The remaining metrical features resemble those of the Type 1 Bush and the South African Negro hyoids or are intermediate between them.

K. 21. An analysis of the metrical values of this specimen elucidates the contrast between the greater cornu and the body of the hyoid. With the exception of the maximal thickness measurement of the greater cornu and the index of the maximal and minimal thickness all the measurements and indices relating to it fall either within the Zitzikama or the Type 2 Bush hyoid ranges, the majority falling in the former range. The measurements and indices of the body show the following affinities. The length is intermediate between the Type 1 Bush and the Zitzikama hyoids. The index of its maximal thickness and height corresponds to that of the average Type 2 Bush hyoid. The maximal height is intermediate between those of the two Bush types, whereas the maximum thickness and the index of the maximal height and length correspond to those of the Type 1 Bush hyoids. No features correspond to any in the Negro hyoid, but the maximal height of the body and the index of its minimal and maximal heights are of the range of the Mapungubwe specimen.

K. 31. This specimen agrees best with K. 21 and thus has more or less identical racial affinities. It differs from it only in that the maximal height measurement and the index of the minimal and maximal heights of the body agree with these features of the Zitzikama specimen, rather than those of the Bush hyoids. The length of the body again is more nearly that of the average Type 2 Bush hyoid than that of the Zitzikama bone.

U.N.M. 7. In respect of a large number of its metrical features, this specimen agrees favourably with the Type 1 Bush hyoid. This statement applies to both individual dimensions and proportions as expressed by the measurements and indices respectively. Other of its features are shared equally by Type 1 Bush and by South African Negro hyoids or are intermediate between these types. At the other extreme again, features such as the maximal lengths of the hyoid or of its greater cornua and the minimal heights of the greater cornua, are entirely of the Negro range. Some of the proportions, in particular, like those of the Zitzikama type or intermediate between this type and the Type 2 Bush hyoids The remaining metrical features are inter-

mediate between those of the Bambadyanalo, Zitzikama and Mapungubwe types.

A.D. 382. In respect of practically all its metrical features this hyoid conforms to those previously established for the South African Negro.

COMMENT.

This investigation has once more convinced me of the value of the hyoid bone as an index of the anthropological status of the individual to whom it belongs. I have been fortunate in having had, both in the present and the previous investigations, collateral evidence as to the racial affinities of the hyoids examined. This has enabled me to attach definite labels to the distinctive types discovered in the first series of bones and to differentiate the racial elements present in the hyoids of this series.

Specimen A.D. 658 is definitely not a pure Bush type. This is to be expected from the fact that the individual to whom it belonged lived in the Southern Kalahari, north of the Orange River. Members of the department of anatomy who had been able to study his physical features, moreover, also recognised this fact. In character the majority of the features of this hyoid are either South African Negro, Type 1 Bush or intermediate between these. As shown previously, the Type 1 Bush hyoids are representative of the Bush race north of the Orange River. The evidence further is that these people are of mixed origin. The specimen also possesses similarities with the Zitzikama type as well as certain other distinctive features.

In the case of K. 21 of the Bambadyanalo deposit there exists the unique combination of features of, on the one hand, a greater cornu having affinities solely with the Zitzikama and Type 2 Bush hyoids and, on the other hand, a body in which Mapungubwe, Bush and Zitzikama features are represented.

K. 31 is very like K. 21 on the whole. But some of its features are entirely different and have indeed not been demonstrated previously in any of the other hyoids. These findings are entirely in agreement with evidence obtained regarding the other bones of these two individuals. Throughout his paper Dr. Galloway comments on the fact that these two, but especially K.31, show divergences from the more or less homogeneous physical type of the Bambadyanalo population. The features which he describes as female characteristics of the definitely male K. 31, are probably identical with those recognised in the hyoid bone as representing affinities with the Zitzikama and Type 2 Bush hyoids. That the Negro element has dwindled to Zero in the Bambadyanalo population is certainly true for the hyoids of K. 21 and K 31.

That U.N.M. 7, from Umgababa, represents another instance of racial miscegenation, cannot be doubted from this study.

Here, in a single specimen, may be recognised not only Type 1 Bush and South African Negro admixture, but also a fair measure of the Boskop element, likewise noticed in the Mapungubwe and Bambadyanalo hyoids. In the case of A.D. 658 admixture of Bush, Negro and possibly other unrecognised strains brought about a general reduction of the dimensions of the hyoid. In U.N.M. 7, on the other hand, it seems safe to conclude that the third racial element operative in producing the massiveness characteristic of the specimen, is the large Boskop physical type of which skeletal deposits have by now been found over an extensive part of South Africa. A.D. 382 is a good specimen of the South African Negro type.

Summary.

The five hyoid bones, whose physical features are analysed in this report are: A.D. 658, male, aged 50 years, of alleged Bush stock, from the Southern Kalahari; K. 21 and K. 31. female, aged 25-30, and male aged 21-30, respectively, of the Bambadyanalo skeletal deposit; U.N.M. 7, adult from Umgababa; and A.D. 382, a male Bavenda, aged 29 years.

The morphological and metrical features of these hyoids reveal the following main racial affinities:

A.D. 658: Type 2 Bush and Negro admixture;

K. 21: Type 2 Bush or Zitzikama and Boskop admixture;

K. 31: Virtually the same as K. 21, together with some as yet unknown factor;

U.N.M. 7: Bush, Negro and Boskop admixture;

A.D. 382: Pure South African Negro in type.

In determining these facts the criteria I had previously established for the South African racial hyoid types were adhered to.

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LEGEND TO ILLUSTRATIONS.

Figure 1.—Superior Aspect of Hyoid Bone. (Natural size).

(a) A.D. 658. Alleged Bush Hyoid. (Male.)
(b) M.M.K. 161. Bush Hyoid. Type 1. (Male.)
(c) South African Negro Hyoid. (Male.)

Figure 2.—Superior Aspect of Hyoid Bones. (Natural size.)

(a) K. 21. Bambadyanalo Hyoid. (Female.)
(b) K. 31. Bambadyanalo Hyoid. (Male.)
(c) M. 5. Mapungubwe Sceptre Skeleton Hyoid. (Male.)

Figure 3.—Anterior Aspect of Bodies of Hyoid Bones. (Natural size.)
(a) M. 5. Mapungubwe Sceptre Skeleton Hyoid. (Male.)
(a) A.D. 658. Alleged Bush Hyoid. (Male.)
(c) M.M.K. 161. Bush Hyoid. Type 1. (Male.)
(d) South African Negro Hyoid. (Male.)

Figure 4.—Anterior Aspect of Bodies of Hyoid Bones. (Natural size.)
(a) Zitzikama Hyoid.
(b) K. 21. Bambadyanalo Hyoid. (Female.)
(c) K. 31. Bambadyanalo Hyoid. (Male.)
(d) M. 5. Mapungubwe Sceptre Skeleton Hyoid. (Male.)

Figure 5.—Right Lateral Aspect of Hyoid Bones. (Natural size.)
(a) A.D. 658. Alleged Bush Hyoid. (Male.)
(b) M.M.K. 161. Bush Hyoid. Type 1. (Male.)
(c) South African Negro Hyoid. (Male.)

Figure 6.—Left Lateral Aspect of Hyoid Bones. (Natural size.)
(a) Zitzikama Hyoid.
(b) K. 21. Bambadyanalo Hyoid. (Female.)
(c) K. 31. Bambadyanalo Hyoid. (Male.)
(d) M. 5. Mapungubwe Sceptre Skeleton Hyoid. (Male.)

A PROJECTED REGIONAL SURVEY OF THE PRE-HISTORY OF SOUTH AFRICA

BY

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Read 5 July, 1938.

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A NOTE ON THE *SHIPALAPALA* OF THE TONGA

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With 1 Plate and 4 Text Figures.

Read 5 July, 1938.

Signal horns, made from the horns of animals, are, or have been, common among the Bantu peoples of South Africa. I dealt with the nature and distribution of such instrument at some length in my book on *The Musical Instruments of the Native Races of South Africa*,* and as a result of my investigations into the use of these horns, I came to certain conclusions as to the number and character of the sounds elicited from them. But an experience which I underwent last year together with an experiment which I conducted this year have caused me to revise my conclusions to some extent, and also to amplify a suggestion which I made in my book.

In order to make the problem clear, I shall describe in outline the chief characteristics of the horns which I had collected or examined prior to the most recent information which has come my way.

The horns generally used for these instruments are those of the sable antelope (*Hippotragus niger*) and koodoo (*Strepsiceros capensis*). The horn of the gemsbok (*Oryx gazella*) is less frequently used. Ox horns are now found in some areas, where game is no longer available.

Apparently, the horn of the sable antelope was the favourite, since its native names, *phalaphala*, *mpalampala* or other variant, are not only applied to the instrument when made from the horn of *Hippotragus niger*, but also to the alternative forms made from *Strepsiceros capensis*, *Oryx gazella* or even from the humble ox. Moreover, the name was in use so early as 1586, for it is mentioned by the Portuguese, dos Santos, as being given to the instrument by the Karanga of that date.†

The method of manufacture was of importance. The maker selected what his experience had taught him was a suitable horn. By means of hot water he would remove the inner core, and, by

* Published by Oxford University Press, London, 1934.

† Theal, G. M., *Records of South-Eastern Africa*, Cape Town, 1901, Vol. VII, p. 203.

laying this alongside the now empty horn, he would determine the position for the *embouchure*, which consisted of a rectangular opening about an inch in length and half-an-inch in breadth, with its edges neatly rounded off. This *embouchure* had to be cut at the point where the tip of the horn ceased to be solid and the "bore" of the tube began.

Now, in the case of those instruments which were made from the horns of the sable antelope, I have found that in olden times the makers took great pains to pare away the ribbing which is so characteristic of these horns, to shape the *embouchure* with the greatest care, and even to ornament the instrument with notches carved in the solid tip. But with the passing of the years the old craftsmanship seems to have died out. At any rate, the workmanship has deteriorated. I possess a series of these instruments, two being Pedi, one Chwana, and one Venda, and in these the deterioration which I have referred to is readily seen. I reproduced a photograph of these four horns on Plate 26A of my book.

But whatever the materials from which these horns were constructed, the music played upon them was of a very restricted nature. Theoretically, such horns, being conical in bore, ought to yield when blown in the manner of a trumpet the tones of the natural harmonic series, but, owing to the fact that the bores of these horns are not always regular, those harmonics that can be produced are not invariably in tune, and the relative shortness of the tubes limit them in number. In fact, up to last year, I had never heard more than two partials of the harmonic series, Nos. 1 and 2, used by native performers upon these signal horns, whatever tribe they happen to belong to.

Of the sable antelope horns in my own collection, three yield the first two partials of the series quite readily, and they are well in tune; a fourth specimen yields the same two partials, but the higher of the two is a semitone sharp. A gemsbok horn in my collection also yields the first two partials well in tune. In all these instances the fundamental sound is B flat or B.

Fig. 1. 

A koodoo horn, made by a Tonga, or Shangaan, as this tribe is popularly known, likewise yields the same two partials of a series of which the fundamental is D, but the second is a semitone sharp, thus

Fig. 2. 

The ox horns give only the fundamental of the series; they would appear to be the most recent development, and represent the most degenerate form of the instrument.

[*Photo by Miss Elaine Gill, Sept , 1937*

Koodoo Horn Blower at Skukuza Kruger National Park

To face Page 36

I use the word "degenerate" because certain evidence which I have now obtained would appear to indicate that individual makers may have existed in the past who demanded more of the instrument than is generally asked for to-day.

On 30th May, 1937, the South African Broadcasting Corporation gave an "actuality" broadcast from the Kruger National Park. By the merest chance, I "listened in," and was very surprised to hear, by way of an introduction to the broadcast, a performance of dance songs by the Tonga natives at Skukuza rest camp, the songs being introduced by calls upon the *shipalapala*, or trumpet made from the horn of the koodoo.

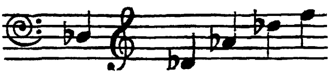
But what struck me most forcibly was that the player extracted four partials of the harmonic series from his instrument, *and these were all in tune.*

The four partials were:

Fig. 3.

At my suggestion, Principal Raikes, of the University of the Witwatersrand, wrote to Col. Stevenson Hamilton, warden of the Kruger National Park, to ask if the native would be willing to part with the instrument. He was, however, informed that nothing could be done until the end of the season. But during my absence in Europe, Col. Stevenson Hamilton again communicated with Mr. Raikes, telling him that the native would not part with his horn. but was quite willing to make an exact duplicate. This he did, and the instrument was waiting for me on my return from overseas.

On this specimen I can sound no fewer than five partials of the harmonic series all in tune. These are:

Fig. 4.

It is, of course, quite possible that the original instrument could yield these five sounds as well as the duplicate, but I heard only four used during the broadcast. But what seems to me to be of paramount importance is the fact that the maker was able to construct *two* such perfect instruments. I would suggest that it is quite possible that he has inherited a type of craftsmanship that has almost died out to-day. Further, I would ask the question whether one should merely regard these instruments as unusual specimens, or consider them to be survivals of the true type of signal horn. The harmonic series is known to the Southern Bantu as a characteristic of their stringed instruments, and to some tribes through their flutes; it would appear to be strange if they had overlooked its occurrence in instruments of the trumpet class, especially when we consider that our modern brass instruments, which one and all yield the harmonic series, have been evolved from just such animal prototypes.

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A PRELIMINARY REPORT ON STONE STRUCTURES NEAR STEYNSRUST, ORANGE FREE STATE

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With 2 Plates and 2 Text Figs.

Read 5 July, 1938.

Introduction.

The bee-hive type of hut was first described by Prof. van Riet Lowe in 1927, in "A Preliminary Report on the Stone Huts of Vechtkop." In 1930, Prof. and Mrs. Hoernle reported on an analogous settlement on Tafelkop near Bethal. Dr. P. W. Laidler wrote on the archæology of certain prehistoric settlements in the Heilbron area in 1935. These settlements are known to be widely distributed over the north-eastern part of the Orange Free State and the Southern Transvaal To the best of my knowledge, a thorough, systematic excavation of any of these settlements has never been undertaken.

The Special Justice of the Peace at Steynsrust first reported the presence of phehistoric native settlements in that area. In a letter to Prof. van Riet Lowe he states that native kraals—" statte "—are situated on the farms Platkop, No. 2243; Ellensrust, No. 144; and Goede Hoop, No. 1853.

Prof. van Riet Lowe entrusted me with the task of preparing a preliminary report on these sites, in order to ascertain whether or not they merit a systematic archæological survey, as well as for the information of the Historical Monuments Commission.

Towards the end of November, 1937, I went to Steynsrust to make a rapid inspection of the settlements. I found that the settlement mentioned above extends on to the farm Spioenkop, No. 1550. I was fortunate, also, to discover that two similar settlements are situated (i) on the farms Jaskraal No. 91 and Stella (portion of Jaskraal); (ii) on the farm Mooi Hoek No. 1103.

Without the generous assistance of the people I met at Steynrust, my task would have been most difficult; my thanks are due particularly to Messrs. Bester, G. Prinsloo and D. Lange for the time which they spent helping me with my investigation.

I further wish to place on record my gratitude to Prof. van Riet Lowe for the opportunity he gave me of visiting Steynsrust, and for the trouble he took in arranging various matters.

Last but not least, I must thank Dr. L. H. Wells for his constant interest and welcome aid in the preparation of this report.

Description of Settlements.

The three sites mentioned above lie in a line running roughly north and south through Steynsrust. For convenience, I will call the first group the Ellensrust settlement, the second the Jaskraal settlement and the third the Mooi Hoek settlement.

1. The Ellenrust settlement is situated off the main road between Steynsrust and Edenville, about eight miles north of Steynsrust. It is spread over a large area and consists of about 10 separate statte.

2. The Jaskraal settlement lies on the road between Steynsrust and Senekal. about two miles south of Steynsrust. Some of the huts and cattle enclosures of this settlement are still in very good condition. The settlement also consists of about 10 separate statte.

3. The Mooi Hoek settlement is the best preserved of the three. It lies about nine miles north-west of Senekal, and is made up of approximately 10 statte. Six of these statte lie along a ridge about a mile north of the farm house, the ridge runs from south-east to north-west, and the statte are situated along the northern edge of the hill. The other statte are spread about on neighbouring hills.

At the north-western end of the above mentioned ridge, there is a hollow separating it from a prominent hill upon which there is a large stat, in the dip between these hills there are a number of small mounds of stone and a single semicircular wall opening out to the west. This site has the appearance of a cemetery. I could not make out for what purpose the wall was built, there are no huts near it and the nearest statte are situated about 200 yards to the east.

At Mooi Hoek the nature of the landscape is hilly, whereas at Ellensrust and Jaskraal it is of an undulating character with small hills and large shallow valleys. The statte at all the sites are situated along the most prominent ridges in the neighbourhood. Nowhere in the valley is there any indication of similar settlements.

The material used for building the statte is ironstone—"ysterklip." It has weathered differently at the different sites, and the builders used the material as they found it in their neighbourhood. At Mooi Hoek and Ellensrust the stones used are flat, while at Jaskraal, more rounded material was used.

Only at Mooi Hoek could I find any indication of burials covered with stones. At the other two sites, burials were probably made in the refuse dumps. At Spioenkop a skeleton was unearthed from one of the dumps, the skull of this specimen is preserved in the Town Hall at Steynsrust. The rest of the skeleton

which is very fragmentary. I recovered from the spot where it had been dumped by the original discoverer.

On none of the sites could I find any evidence of a stone culture. Apparently the inhabitants worked chiefly in iron. Although I found no iron implements or slag, the farmers have from time to time found iron arrow-heads in the statte.

Potsherds are found in abundance. and excavation of some of the refuse dumps would undoubtedly result in the discovery of a wealth of such material

Stone grinders were originally present in great numbers at all the sites, but unfortunately these are being removed by the natives in the district for their own use.

Description of Statte.

In their general characteristics the settlements correspond closely to those previously described. There are, however, certain features which have not yet been noted, and it is with these only that I propose to deal here.

(1) The area between the central cattle enclosure and huts in some of the statte on the Mooi Hoek settlement has all the appearance of having been paved as cross-hatched in Fig. I a.

(2) The doorways are not always built into the walls of the huts in the same way. In some cases the entrance is built into the side of the circular wall, and opens towards the centre of the hut. In other cases the entrance does not open towards the centre of the hut, but is built at right angles to a more or less straight internal wall (Fig. I b and c). Intermediate stages are also found.

(3) In only one hut (Ellensrust) a second opening had been provided as shown in Fig I d. This hut also has an exceptionally high entrance (Plate II A).

(4) The fourth unrecorded feature is the existence of low stone screens or wind-breaks (?) for the protection of the hut entrances as shown in Fig. I e and f and Plate I b. These hut screens are built of uncemented undressed stone as are the huts and cattle enclosures.

(5) Fig. I g is a diagrammatic cross-section of a hut. It shows how the inner wall (i) is corbelled or cantilevered and counter-weighted with rubble (iii), while the outer wall (ii) is battered, apparently to keep the rubble in position.

6) Among the most interesting new features are the small domed structures found at Ellensrust and Mooi Hoek.

These miniature huts are built on similar lines to the larger ones. but on account of their size and the ease of corbelling so small a dome, have not got double walls.

Average dimensions are: (i) internal diameter, 3 feet; (ii) internal height, 2 feet; (iii) entrances, 18 inches x 18 inches; (iv) thickness of walls, 12 inches.

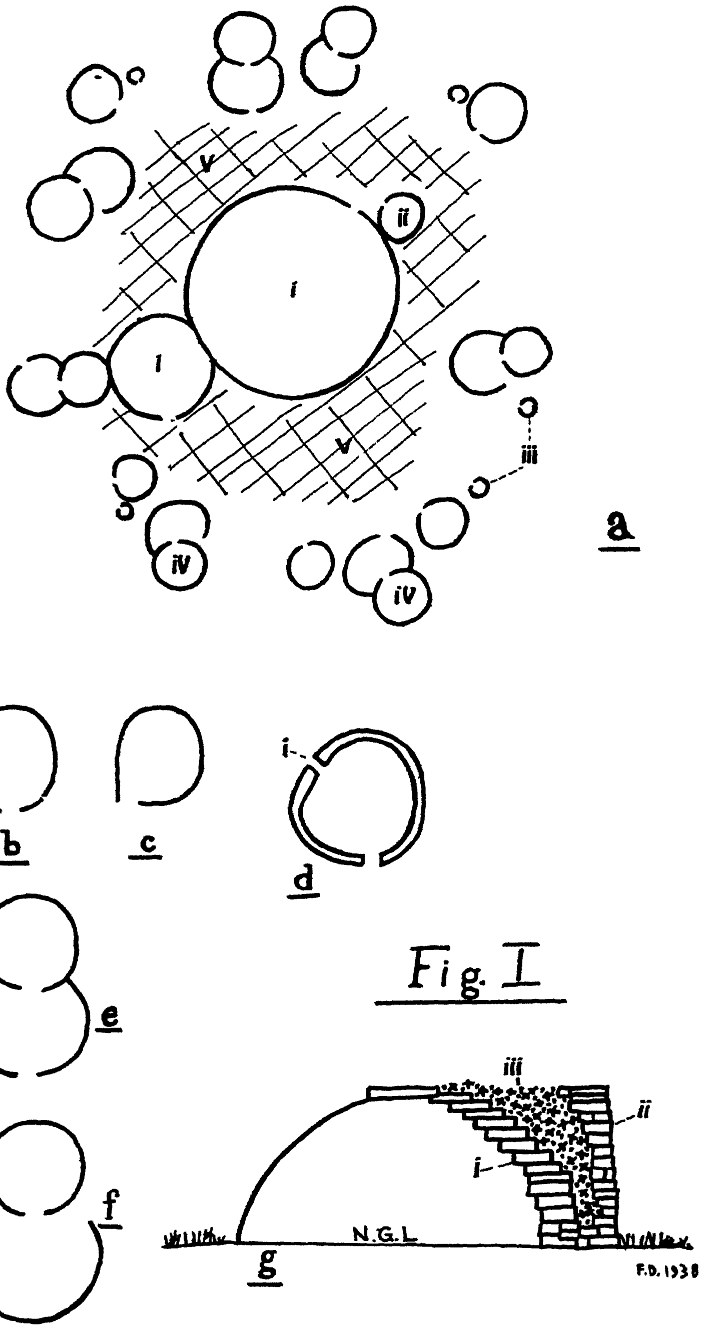


Fig. I

They are generally found next to the dwelling huts and were probably used as storerooms.

(7) The cattle enclosures are built on the usual circular plan as described previously. Plate I C shows a cattle enclosure and the remains of a shepherd's hut in the bottom right-hand corner.

(8) Plate I B shows a hut and hut-screen on the Mooi Hoek settlement. A comparison with Plate I A and Plate II C shows the difference in material used at Mooi Hoek and Jaskraal. Plate II B typifies the material used at Ellensrust.

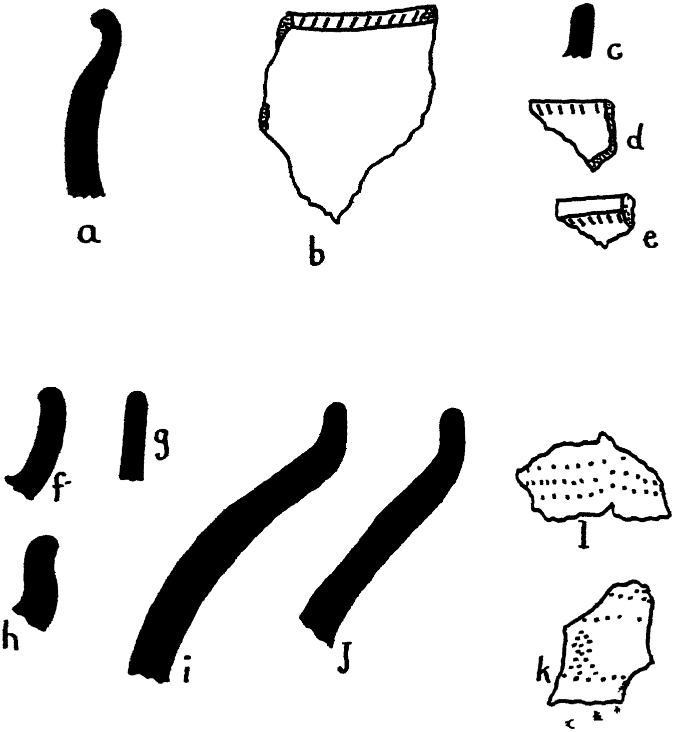
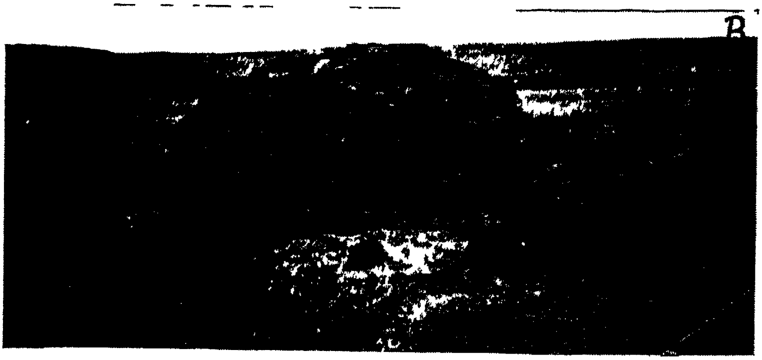


Fig. II

Potsherds from Ellensrust : a, b, and i, and from Jaskraal c–h and J–l.



Stone Structures near Steynsrust.

A—Large hut on Jaskraal.
B—Hut and screen on Mooi Hoek.
C—Cattle enclosure and shepherd's hut on Mooi Hoek.

To face Page 368

A—Doorway of hut on Spioenkop.

B—Hut and small domed structure on Spioenkop.

C—Hut on Jaskraal.

To follow Plate I

Description of Finds.

The only artefacts collected from these sites were potsherds recovered mostly from the farm Stella of the Jaskraal settlement.

The sherds are mostly of a grey clay containing small particles of quartz; their surface is red or brown in colour, with a smooth finish, occasionally, burnished. As Fig. II shows, there is considerable variation in the form of the vessels represented. Two forms of decoration have been found, both executed on the wet clay, viz. incisions on the outer edge of the lip (Fig. II b and d-e) and small circular, pin-point impressions seemingly forming part of an extensive design (Fig. II k and l).

Another most interesting fragment, not illustrated, was found at Stella. It is a fragment of a spoon made of coarse black clay with a rough red surface. The bowl of the spoon, when complete probably measured 1½ inches in length by 1-1½ inches in breadth. Its edges were unevenly moulded giving it more depth on the right hand side. The handle at its junction with the bowl is round and measures ⅜ inch in diameter.

It must be emphasised that the pottery here described was collected on the surface, hence its fragmentary character. Excavations in the ash-heaps on these sites would undoubtedly produce much more complete and more abundant material.

Conclusions.

Mooi Hoek is the best preserved of the three settlements, all the main features seen at the other settlements are to be found here too.

Mooi Hoek has some interesting features of its own, as it stands to-day, much valuable information can still be obtained from it, but the huts and cattle enclosures are being broken down rapidly. Interesting implements, potsherds and the like are being exposed and subsequently either destroyed or removed.

Rodents are gradually undermining all the refuse dumps, and soon the site will be lost to the archaologist.

Mooi Hoek, I am convinced, would repay a thorough systematic archæological survey and until this can be achieved, it is gratifying to record that steps are being taken by the Historical Monuments Commission to protect the settlement.

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Fig. 1.

a—Sketch of stat at Mooi Hoek. i Cattle Enclosure. ii Shepherd's hut. iii Small domed structures. iv Huts with hut screens. v Area of paving.

b and c—Doorways.

d—Hut on Spioenkop. i Opening in straight wall.

e and f—Plans of Hut Screens.

g—Diagrammatic section of wall of hut. i Inner corbelled wall. ii Outer wall. iii rubble counterweight for inner wall. N.G.L. natural ground level.

(see Plate Ia.)

Fig. II.

a, b—Sherd with decorated rim from Spioenkop (Ellensrust settlement) in brown smooth-surfaced ware.

c, d, e—Sherd with decorated rim from Stella (Jaskraal settlement) in red smooth-surfaced ware (? burnished on inner face).

f—Undecorated rim-sherd from Stella, in red smooth-surfaced ware.

g—Undecorated rim-sherd from Stella, in grey rough-surfaced ware.

h—Undecorated rim-sherd from Stella, in smooth-surfaced ware, brown externally and red internally.

i—Upper portion of pot from Spioenkop, in red rough-surfaced ware.

j—Upper portion of pot from Stella, in brown smooth-surfaced ware.

k, l—Sherds with impressed decoration from Stella in smooth-surfaced ware, red externally and burnished brown internally.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 371-381, December, 1938.*

THE MAKAPAN CAVES. AN ARCHÆOLOGICAL NOTE

BY

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With 3 Figures.

Read 5 July, 1938.

1.—INTRODUCTION (1925).

In a brief note on certain cave deposits on the farm Makapansgat in 1925, Professor Raymond A. Dart described an occurrence of bone breccia "containing thousands of comminuted bone fragments." Because the deposit seemed to be of the cave variety and some of the bone fragments had a blackened charred appearance, Professor Dart concluded that "the agency of man in its formation was highly probable." A careful examination of charred remains revealed particles that "had an appearance similar to that of carbon particles under the microscope." By means of transformation into carbon dioxide, a considerable percentage of the element was demonstrated chemically. Although no human bones or implements had been found in the deposit, he concluded that "there seems to be little doubt from the evidence available that the bone bed is the 'kitchen-midden' result of human occupation at a remote epoch." (1).

Four cases containing remains removed from this breccia were sent to the Director of the South African Museum at the time. When I recently wrote to the Director for information he replied saying: "We have a few broken bits of bone and teeth, together with a letter, from Mr. Wilfred Eitzman addressed to Professor Dart, dated 27th May, 1925.

"No description of this material has been published, nor is it in good enough condition for description."

2.—JANUARY, 1937.

At the request of the Commission for the Preservation of Natural and Historical Monuments, Relics and Antiques, I visited the farm Makapansgat (No. 347 in the district of Potgietersrust, Central Transvaal) during January of last year in order to complete a report on the historic significance of this interesting area.

After an inspection of the great cave in which Commdts.-General P. G. Potgieter and M. W. Pretorius and their men (including Field Cornet Paul Kruger) ultimately revenged themselves of the brutal murder of twenty-three women and children at Moorddrift in 1854 (2), I continued to examine further caves in the vicinity. During this examination I noticed repeated occurrences of bone breccia and in one particular cave discovered what I took to be a hearth *in situ* under an appreciable deposit of breccia. A deep drive had been cut through solid rock to give access to an especially rich lime deposit. On one side of the drive there is an extensive exposure of bone breccia below which, at a depth of about twenty feet from the surface, I noticed a layer that had all the appearance of a hearth. It was several inches in depth and exposed over a length of about six feet. The material in this layer was fine, loosely consolidated and ash-like in appearance. A sample was brought away and submitted with a report to the Director of the Geological Survey who replied "that the black-looking stuff from the floor of Makapansgat contains a fair amount of free carbon and that the hard stuff" (from the same layer) "carried some glassy material and seems to be a slag with a little free carbon. It looks as if your suggestion of a hearth is correct, unless," he added with caution, "the slag is due to some sort of natural fire."

As the cave to which I referred in my reports to the Director of the Geological Survey and the Commission for the Preservation of Natural and Historical Monuments, Relics and Antiques had only recently been exposed, it could not possibly be that to which Dart referred thirteen years ago. The concluding passages of my report dated 6th February, 1937, contain the following paragraphs:

"The possibility that the stratum with free carbon and slag is due to natural agencies in the particular situation in which it occurs is I feel, very slight, though it naturally cannot be ruled out at this stage.

"Very considerable damage has been done by blasting operations in connection with the locally established lime works as well as by amateur fossikers and self-styled scientists whose visits to the caves are both numerous and frequent." My report concluded with a strong recommendation that protective steps be taken without delay.

Reference to the occurrence was also made in my Annual Report for that year (3).

3.—June, 1937.

In June of last year I revisited the site and found the right face of the drive had collapsed along a more or less horizontal line half way up its face. Large and small blocks of breccia were strewn all along the floor of the drive and in the floor of

the cavern created by the collapse. The photograph in Figure 1 and the cross-section of the drive in Figure 2 show what had happened. Both views are looking down the drive toward the tunnel (marked T in Figure 2) that gives access to rich lime deposits below. Originally the two vertical faces of the drive were along the lines XL-XL and XR-XR of Figure 2. The cavern in the right face is clearly seen in the photograph. The largest block of fallen breccia is marked "B." The upper surface of this block was found to be composed of a mass of broken bones and stone artifacts and a little examination soon showed that the collapse was due to a plane of weakness created by an occupation level in the original cave. The level of the hearth discovered during the previous visit is indicated by an "H" in Figure 2. This is on the floor of the original cave. The "O" indicates the occupation level along which the collapse occurred some ten to twelve feet vertically above the hearth "H." Every block of breccia derived from between the levels "H" and "O" was found to contain masses of completely mineralised bone fragments and abundant traces of human industry.

The roof of the cavern created by the collapse was found to be the mirror-image as it were of the upper surfaces of the detached blocks lying below and scores of broken bones and stone artifacts could be seen projecting from or exposed in the breccia in the roof.

Despite the fact that the breccia was found to contain masses of stone flakes, chips, rough cores and "hammer-stones" of felsite and quartz which very obviously had been brought there by human agency, only two recognisable implements were recovered. These are illustrated in Figure 3. Both are bifaced tools in felsite and both were recovered from fragments of breccia derived from below the occupation level "O." Professor and Mrs. R. F. A. Hoernlé and Mr. F. R. Paver of Johannesburg were with me at the time of the discovery. These bifaced tools —half hand-axe, half cleaver—were made on large side flakes derived in the Victoria West (or Proto-Levallois?) manner. The upper specimen is a guillotine-type cleaver well trimmed on both faces and lenticular in cross-section over the minor axis; the lower specimen is equally well trimmed over both faces and also lenticular in cross-section over the minor axis. It resembles the guillotine type cleaver but with a median ridge gives one the impression that it is an unfinished or asymmetrical hand-axe rather than a cleaver. Both are of well advanced African Acheulean *type* but until more finished tools have been recovered it is impossible to say whether they belong to the Earlier or to the Middle Stone Age. Tools of this type occur in Stellenbosch, Fauresmith and Middle Stone Age assemblages. The waste flakes suggest a Middle rather than an Earlier Stone Age horizon but it is not possible at this stage to express a final opinion.

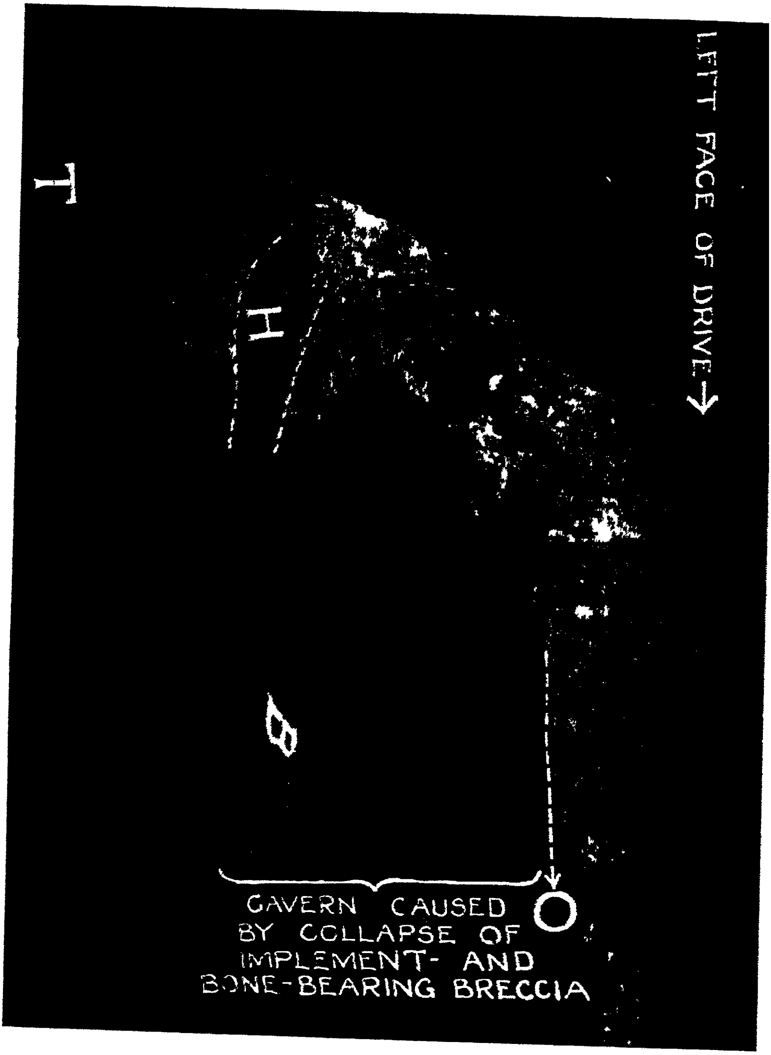


Fig. 1.

Close-up view of cavern in right face of drive after the collapse, showing masses of fallen implement- and bone-bearing breccia. The largest block is marked B. T=tunnel at end of drive. H=bottommost hearth on original cave floor of solid dolomite. O is the occupation level along which the collapse occurred.

There can be no doubt that the accumulation of material between the level of the bottommost hearth at " H " and the occupation floor at " O " was largely if not wholly due to human agency. It is a typical cave deposit of midden type buried under an infill of surface debris derived from the slopes of the hill-side above. The whole—midden and infill—was subsequently cemented into the mass we see to-day. The degree of cementation varies from place to place in both the natural and artificial deposits—as the degree of cementation varies from cave to cave in the valley.

We found it impossible to trace the original entrance to the cave. The hill-side is riddled with caverns — all in the dolomite—and this particular cave was completely filled in. The earliest occupants found it clear and obviously a desirable home-site. The great accumulation of ash and home-and-factory-site waste shows that it was occupied for a very considerable period before it was deserted and ultimately filled in before the whole was cemented by natural processes.

4.—October, 1937.

Accompanied by my assistant, Mr. B. D. Malan, Mr. John Harcus and Mrs. Alice Bowler-Kelley of Paris, I revisited the site last October. On this occasion we came across a hitherto unexamined and undisturbed cave in which the breccia was not so highly cemented as in the others and from the uppermost deposits of which we recovered several flakes and chips. One flake—a specimen in clear quartz—reveals an evolved Lavallois technique and undoubtedly belongs to a Middle Stone Age horizon. No definite tool-types were recovered.

The original cave that yielded the implements illustrated in Figure 3 was naturally revisited. As more breccia had collapsed it was imperative that immediate steps be taken to remove all fallen masses and prop up the remainder for future work.

Appreciating the urgency of the situation and recognising the possiblity of establishing stratification of types (both human and faunal) if such stratification exists, Mrs. Bowler-Kelley immediately and generously offered to defray all expense in connection with this preliminary work. Under expert guidance a gang of labourers was engaged and the work of salvage, propping and safeguarding speedily completed. We must record our deep indebtedness to Mrs. Bowler-Kelley for her public-spirited action.

5.—Preservation.

Since then these caves—obviously not merely " home " but also " factory " sites—have been adequately fenced and proclaimed under the Natural and Historical Monuments, Relics and Antiques Act No. 4 of 1934 and so preserved for proper scientific investigation. We must record our gratitude to Mr. J. H. Hamilton, the owner of the farm " Makapansgat " for his co-operation and ready consent to proclamation.

6.—Faunal Remains from Similar Deposits.

While these preliminary investigations were being carried out, Dr. Robert Broom was busily engaged describing a group of new fossil mammals recovered from similar caves in other parts of the Transvaal. In a recent and very valuable publication on these, he gives the following list:—

Australopithecus transvaalensis, sp. n.
Dinopithecus ingens, gen. et sp. n.
Meganthereon barlowi, sp. n.
Felis whitei, sp. n.
Elephantomys langi, gen. et sp. n.
Crytomys robertsi, sp. n.
Mystromys huislichtneri, sp. n.
Palaeotomys gracilis, subgen. et sp. n.
Procavia obermeijerae, sp. n.
Parapapio broomi.
Equus capensis Broom.
Notochaerus meadowsi Broom.
Vaal rhebok (still living).
Myosorex tenuis.
Bos makapaani, sp. n.
Thos antiquus, sp. n.
Thos adustus.
Leptailurus spelaeus, sp. n.
Crossarchus transvaalensis, sp. n.
Atelerix major, sp. n.
Notochoerus meadowsi.
Procavia transvaalensis.
Meganthereon barlowi.

The list includes " the still living Vaal rhebok " as well as " abundant remains of a game-bird possibly a francolin, and some bones apparently of a large bird of prey." Summing up his work, Dr. Broom adds: " All the mammals so far discovered in the caves belong to extinct species, except a hyaena, a porcupine, the little shrew *Myosorex tenuis* and the Vaal rhebok.

" So far no trace of man has been discovered in any of the caves, and the remains of *Australopithecus transvaalensis* are most probably those of an animal killed and partly devoured by a large carnivore, possibly *Meganthereon barlowi*, remains of which occur in the same cave."

Speaking of the age of his finds, Dr. Broom says: " All the deposits may, I think, be regarded as Pleistocene, but clearly the deposits are not all of the same age, and later on the animals in the deposits in the different caves will be grouped together. At present is seems only necessary to give preliminary descriptions of the various new forms." (4).

In another publication, he assigns the Sterkfontein Ape to the Upper Pleistocene (5).

7.—The Future.

At my request Dr. Broom very kindly examined the Makapan breccia and with the consent of the Commission for the Preservation of Natural and Historical Monuments, Relics and Antiques. we have agreed to conduct a thorough investigation, the results of which will be published in due course. Mr. H. B. S. Cooke has very kindly consented to take charge of the geological side of the enquiry.

8.—Discussion.

My reasons for making this brief statement at this stage are:

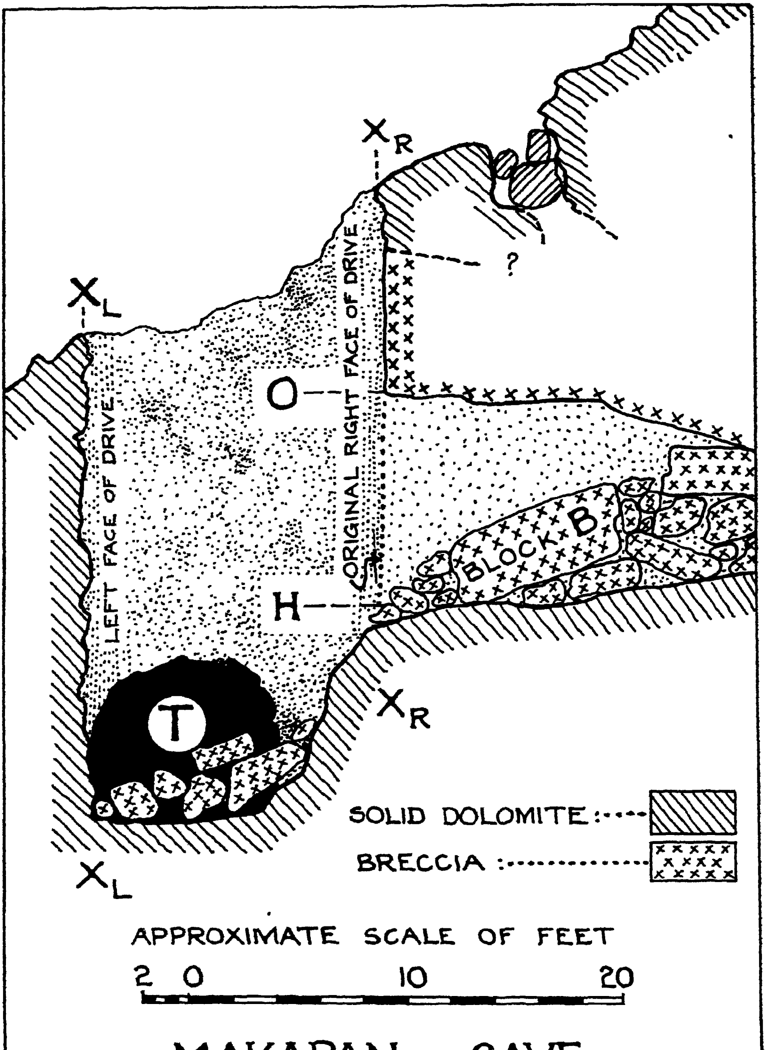
(i) that this is the first record of the discovery of stone implements in a fossilferous breccia that occurs in limestone caves in South Africa,

(ii) that the archæological data from these caves will provide as important dating evidence as the palæontological and

(iii) that the *latest* data that can be assigned to the stone implements illustrated in Figure 3 (i.e. those derived from between the " H " and " O " levels of the main deposit exposed by the drive to the shaft T marked in Figure 2) is the Middle Stone Age.

The Makapan Caves are in a long narrow valley between hills that skirt the north-western boundary of the Springbok Flats. Throughout the Flats tools of the type recovered occur in Middle Stone Age assemblages that are found in grits or laterites in the subsoil. Whether the grits are coarse or fine they represent a period of vigorous erosion and the Middle Stone Age of the Flats may therefore be assigned to a comparatively wet phase. Now it is interesting to observe that in his Explanation of Sheet 17 (Springbok Flats), Wagner devotes a special section to a review of the evidence of climatic changes in the area with which we are dealing. In this he says: " So far as the area under review is concerned, every valley in the elevated tract in its north-western portion tells the same story of (a) vigorous erosion succeeded by (b) an arid period when the streams were overloaded with sediment which led to their valleys being aggraded with fine silt; and finally, (c) renewed vigorous erosion by the present streams which have cut down through the fine silt to bed-rock or to the coarse gravel with which the valleys are floored " (6).

The parallel between this state of affairs and that recorded for the Vaal River Basin is too remarkable to be fortuitous and there can be little doubt that if the tools recovered from the Makapan Caves are found to belong to the Middle Stone Age



X_R
X_L
ORIGINAL RIGHT FACE OF DRIVE
LEFT FACE OF DRIVE
O
H
?
BLOCK B
T
X_R
X_L
SOLID DOLOMITE
BRECCIA
APPROXIMATE SCALE OF FEET
2 0 10 20
MAKAPAN CAVE.

Fig. 2.

Fig. 3.

Two views of two stone implements recovered from bone breccia below the occupation level O.

then the time horizon to which they will ultimately be assigned will most probably be the Third Wet Phase of the Pleistocene as established in the geological survey of the Vaal River Basin (7), viz., the Upper Pleistocene;

(iv) if the age assigned by Broom to the Sterkfontein deposits is even approximately correct—namely Upper Pleistocene—then all the animal remains so far recovered from similar caves—including those of *Australopithecus transvaalensis*—may represent remains of animals that lived side by side with makers of comparatively advanced stone implements;

(v) whether breccia-filled caves in South Africa are in dolomite or other rock formations, they need to be most carefully examined and excavated. Many of us feel that in them we shall yet find some of the most important clues to the activities and associates of early man in this area. Occurrences of breccia that have yielded human or faunal remains are widespread. In the north we have Broken Hill where the bones of Rhodesian Man were recovered in a breccia-filled cave at depth below the surface (8). Many artifacts of Middle Stone Age facies were also recovered but the whole was recklessly exploited for commercial purposes and such valuable evidence as might have been noted was irretrievably lost.

Further south we have the breccia-filled caves of the Central and Southern Transvaal and the Northern Cape. The Taungs and Sterkfontein caves are being commercially exploited and such palæontological data as has been gathered, valuable though so much of it is, is meagre in the extreme—meagre because so much of the evidence that is yet available is being neglected or destroyed.

Breccia was also noted in the Cango Caves and in the extreme south-west of the Cape I have seen stone implements embedded in the roof of a cave known as "De Kelders" at Gansbaai near Hermanus. This cave must at one time have been part of a larger cavern that ultimately became filled with breccia and a collapse—perhaps not unlike that which I have described from Makapansgat—gave rise to the cavity in which to-day we have a mineral spring and a natural reservoir of supposedly curative waters. Incidentally it provides an interesting object-lesson to us all in that it tells us that we must not only examine the floors of caves for signs of human habitation, but also the ceilings!

It is unlikely that the breccias to which I have referred are all of the same age, but it is imperative that they be safeguarded against reckless exploitation. Those who exploit the commercial value of the deposits are all reasonable men if properly approached and much extremely good work could be done if the co-operation of these men is invoked. The Commission for the Preservation of Natural and Historical Monuments, Relics and Antiques of which it is my privilege to be a

member, is straining every effort to preserve these deposits for proper scientific investigation. Members of this Association could do much to support this work of the Commission. Where the danger of destruction is present members or anyone interested should submit a report to the Commission so that timely measures may be taken to preserve the occurrence for examination. We have the machinery to do this, so let us make use of it. The Commission would welcome such reports for *at least* they afford an opportunity for examination before or during operations of a commercial nature while, *at best* they may provide grounds for the proclamation of the site in order to preserve it until a thorough investigation is possible.

9.—Conclusion.

In conclusion, I would like to express my admiration for the insight and daring displayed by Dart thirteen years ago. Like me he felt that if traces of human industry were found in these breccias, they would in all probability be very old and like me he will, I feel sure, experience considerable suprise when he realises how advanced the humans were who occupied these limestone caves before their hearths were buried and the caves themselves completely filled in with sand and rock fragments, the whole of which (hearths and in-fill) was subsequently cemented into the breccia we see to-day.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 382-395, December, 1938.*

POTTERY FROM NATAL, ZULULAND, BECHUANALAND AND SOUTH-WEST AFRICA.

BY

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With 3 Text Figures.

Read 5th July 1938.

(1) *Three Pots from Glenwood High School, Durban.*

This very fine family of pots, illustrated Fig. No. 1 (1), was unearthed, reputedly at a depth of about five feet below the present ground surface, during the process of excavation for the foundations of Glenwood High School in 1929. Exact details are lacking, as little notice was taken of the pots at the time of their discovery. Fortunately, they were not destroyed, but lay almost forgotten until last year, when their value was realised, and they were presented to the Durban Museum.

The importance of these pots lies in the fact that they are perfect examples of our Class NC_2a Pottery, which we have associated, in Natal, with an iron using, rather than with an iron smelting, culture.

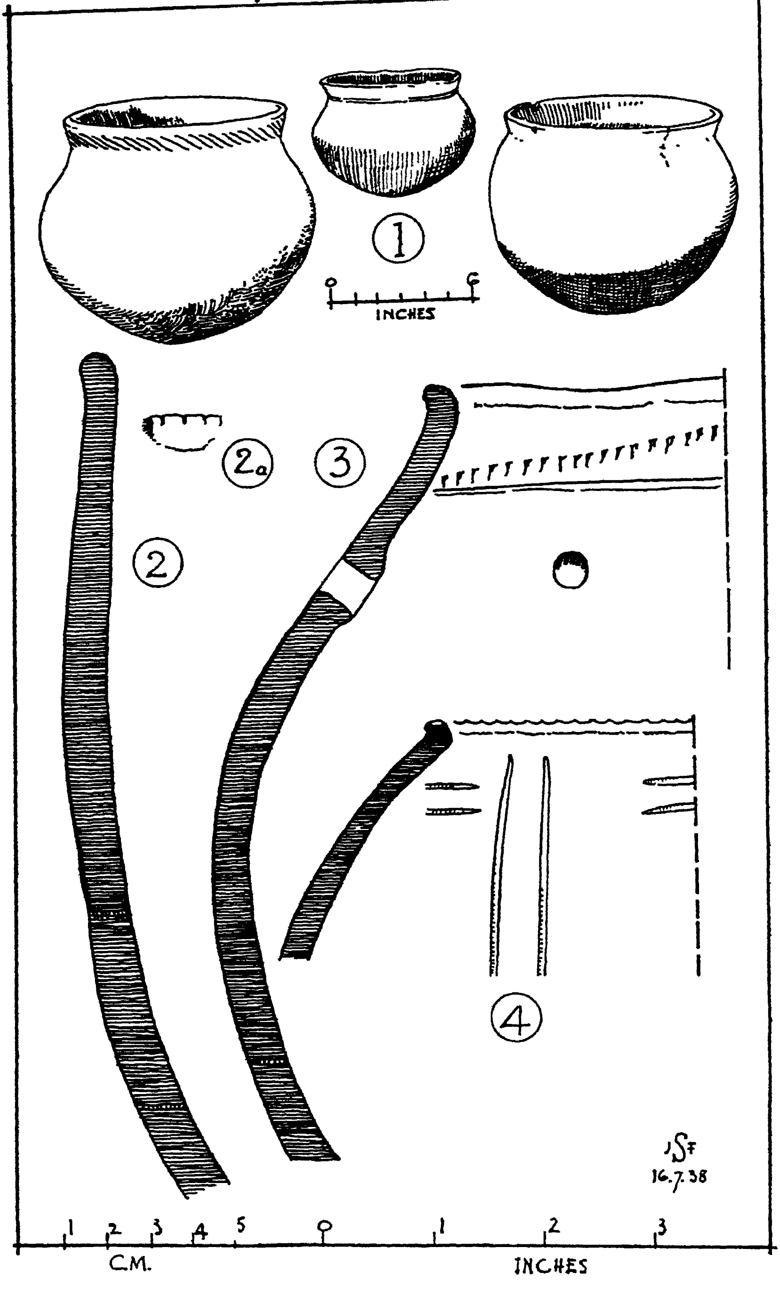
Each of these pots has a short flared neck. The clay is a dark grey, and seems to have been finished to a brown matt surface, which is now very powdery. The sections of the rims are identical with pottery recovered from a depth of eight feet at the Durban North Reservoir. As we have already pointed out (NCP., 1 and 2), this class of pottery is very like material described by Dr. van Hoepen from near Zeerust, in the Western Transvaal, which may have been the work of a branch of the same people. If this surmise prove to be correct, then we may describe our pottery as being of Sotho origin.

(2) *An Unusual Pot from Durban.*

This pot, which is illustrated on Fig. No. 2 (1) and (2) was discovered at a depth of 8 feet below the surface of the ground, during the excavation for the foundation of a building at No. 127 Sydenham Road, Durban, and owing to the timely interest of the builders, Messrs. Powis & Co., it was saved from destruction, and presented to the Durban Museum.

Sydenham Road follows the track of an old donga, which ran from the Berea ridge down to the vlei, which is now occupied by the Race Course. In the section which now lies between

TEXT FIGURE No 1



Musgrave and Essenwood Roads, the land on the northern side of the donga rose to a height of about 20 feet above the present surface of the road, and was formed of an upper layer of fairly loose brown sand, about 7 feet in depth, overlying the consolidated red Berea sand. It was just below the junction between these two types of sand that our pot was found.

Description of the Pot.

The pot appears to have been given a brown burnished surface finish, which has weathered off almost entirely, leaving the soft black clay of the pot wall exposed. The rim, which is cut square, is 3 inches in diameter, and the height, and the greatest diameter of the pot are both 5¾ inches. The general design seems to suggest that we have here the combination of the upper part of a spherical pot, with the smallest member of the Glenwood family. Fig. No. 1 (1). The upper portion of the pot slopes from the rim with a downward curve and meets the neck with a slight roll, below which there is a line of vertical stitch-like impressions. The neck has an ovolo section, and is separated from the body by several irregular lines. The upper part of the body is slightly conical, and the lower part is hemispherical.

DISCUSSION.

From the above it will be seen that both the design of this pot, and the material of which it was made, indicate that it should be included in our Class NC_2a, while the position in which it was found in the consolidated red sand, suggests that it may have formed part of a burial deposit of a considerable antiquity.

(3) *Pottery from Uqupu and Mapumulo.*

The pottery from these two sites was discovered by Captain A. G. McLoughlin, to whom our thanks are due for placing it at our disposal.

Uqupu.—The Uqupu site lies on the sand dunes to the south of the mouth of the Umhlatuzi River. Near the site is a marshy tract abounding in lemonite, which has been extensively used in the past as the source of the iron ore for an extensive smelting industry, of which the slags are at present scattered over the surface of the site, where they are mixed with midden material, bones and fragments of pottery.

This pottery appears to belong to the classes we have called NC_2 and NC_3. The former is represented by a Beaker Bowl, similar to Fig. No. 2 (8), (NCP. 2), but with a single line of circular impressions; a Flared Bowl, similar to Fig. No. 2 (6), (NCP. 2) and the latter by the fragments of a large pot with a flared and everted neck, similar to Fig. No. 2 (15).

The pot from this site which we have illustrated, Fig. No. 1 (4), was about 6½ inches over the rim, and if, as we suspect, it was spherical, it would have been about 8¼ inches in height. The clay was fine, of a greyish colour, and burnt from a dark grey to

a light buff matt surface. The rim was rounded, slightly rolled, and notched at about $\frac{1}{8}$in. centres. The exterior of the pot appears to have been divided into four sections by pairs of vertical lines, with two horizontal lines in each section, just below the rim. All the decoration was cut on the wet clay in a rough but effective manner.

DISCUSSION.

In the pot before us, the type of clay used, and the notching of the rim are both characteristics which we have learnt to associate with the Class NC_2 wares, but the free use of lines in the decoration probably represents a blending between that class and NC_3 pottery, or perhaps more recent wares.

We can conclude, therefore, that the site at Uqupu represents precisely the same conditions as those with which we have described at Tongaat, Tinley Manor, Umhloti and other coastal sites farther south.

(4) *Pottery from near Mapumulo.*

The site of the discovery of this pottery is at a point four miles from Mapumulo on the Stanger Road, where a cutting has exposed a section showing a bed of gravel 4 inches in thickness, containing artifacts of the Tugela type; this is covered by a layer of humus from 12 to 20 inches in depth, in which the pottery sherds were found at a depth of about 18 inches beneath the surface

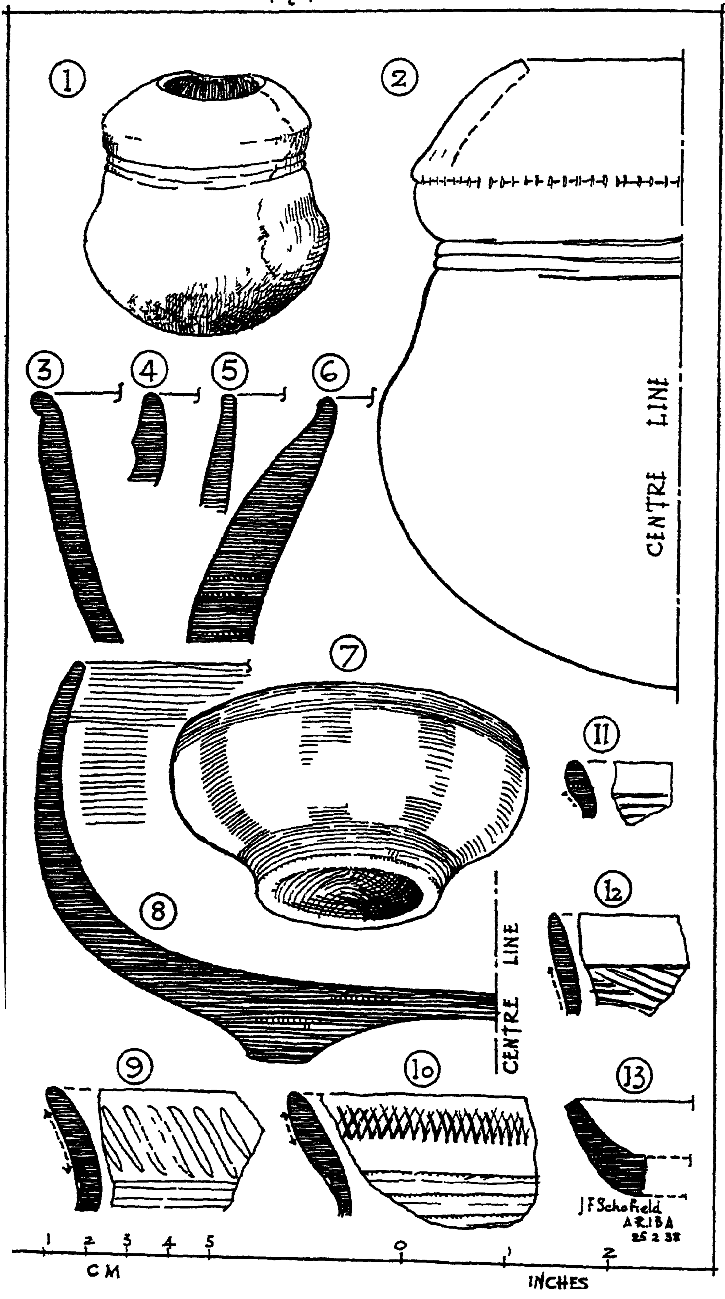
It has been possible to assemble a sufficient number of the pieces to show that they belong to a Beaker Bowl, illustrated Fig. No. 1 (2) and (2a), which was about 13 inches over the rim, and which had a height of about 10 inches, but this dimension is very uncertain, as it is impossible to decide whether the base was rounded or flattened. The rim was rounded, and in part at least, decorated with short transverse notches, very similar to the pot from Tinley Manor, which is illustrated on Fig. No. 2 (9), (NCP. 2). The clay was soft and of a dark grey colour, burnt to a red surface which had been smoothed, and has now a greyish-yellow patina.

DISCUSSION.

The interest of this pottery lies in the fact that it was found in a stratified deposit, and is obviously of a considerable age. We believe that its place in our pottery classification can be settled by a reference to Fig. No. 1 (PI), where a section of the sand dunes at Tongaat is shown. Layer "E" of this section contained in Class NC_3 pottery, and from layer "D," which is directly below it, we recovered large fragments of a very similar pot to the one under review, and the globular pot with a short flared neck, illustrated in Fig. No. 2 (5), (NCP. 2), which is so characteristic of our Class NC_2a wares.

It would seem that it has much in common with the pottery discovered in the Umgazana Cave in Pondoland (PU.), which is

TEXT FIGURE Nº2



the only pottery hitherto described as having been found in close association with artifacts belonging to the late Stone Age Industries of the Coastal Area.

We conclude, therefore, that our ware belongs to Class NC_2a of the Coastal Pottery Series, which we have suggested may have been due to the early stages of the Bantu cultural influence.

(5) *A Spouted Pot from Weenen Commonage.*

The pot illustrated in the accompanying text figure, was discovered in fragments on Weenen Commonage by Mr. E. Thomasset and presented to the author. In making such reconstruction of the pot as the condition of the material permitted, it was noticed that it had originally a spout, for the body just below the neck had been pierced before burning, and the scar where the spout had been attached was visible. The proposed restoration, Fig. 1 (1), shows what was in all probability the original appearance of the pot.

DISCUSSION.

The occurrence of Spouted Pots in South Africa is of a very sporadic distribution, and they seem to be the exception rather than the rule, whether they owe their origin to the Hottentot or the Bantu. Examples of the former have been illustrated by Laidler (HBP.) and Wells (CSA.), while an excellent example is to be seen in the National Museum, Bloemfontein. So far as we are aware, the only spouts which could be reasonably classed as Bantu, with the exception of the one under review, were taken on the Limpopo sites in the Northern Transvaal, where a dozen were found, and the four from Tinley Manor site in Natal.

Amongst our modern natives, the only people who make Spouted Pots appear to be the Lunda of the Mwimilunga District of Northern Rhodesia.

All these spouts have been classified as:—

(1) Tubular.

(2) Channelled.

(3) Bridged, to which category our example belongs.

The Weenen Pot is of particular interest because, unlike all the other Spouted Pots of a Bantu facies, it was decorated, and thus we are able to classify it with our NC_3 ware, which is associated in Natal and Zululand with the extensive iron working industry which may have been carried on during the 17th and 18th centuries by the Lala peoples. Quite recently the relation which existed between the smelting of iron and this class of pottery, has been further emphasised by the discovery, at Hillery, near Durban, of a deep deposit of iron slag covering several hundred square yards. Mixed with it are innumerable tuyiers and pieces of this class of pottery, both of which were made from identical material.

This pot may further be described as—

A Spherical Pot with a short everted neck, 8 inches over the rim, 10 inches in diameter, and about 8 inches in height, in a light grey clay, the surface of which is at present coloured a deep yellow ochre. It is impossible to make any decision regarding the original finish. as all the fragments show considerable weathering.

The rim is cut square and bevelled outwards, the neck is everted and decorated with alternate groups of horizontal and nearly vertical hatching. Below this is a rounded band decorated with deeply incised herring-bone, below this is another similar band, which appears to have been plain, with the exception of a small amount of hatching on its lower half, below this again are more band both of which are decorated with herring-bone.

The upper part of the body has a wide zone with at least one large counter-hatched triangle, and with a further decoration of irregularly placed strips of hatching.

The pot wall at the junction of the neck and body was pierced, before burning, with a horizontal hole, ⅜in. in diameter, and a spout, now unfortunately lost, was welded on to the exterior of the pot wall in continuation of this hole.

All the decoration was cut on the wet clay.

(6) *Pottery from Bechuanaland.*

This pottery was collected from superficial deposits in Bechuanaland by Mr. James Swan of Kimberley. As very little is known of the wares of this Territory, we believe that, despite its fragmentary condition. it is of very real interest.

The Pottery from Kheis.—The pottery from Kheis, which is situated on the Orange River about 70 miles below Prieska, has several interesting features, and may be classified into two groups.

Group I.—This pottery is fine and well burnt, the clay was a dark grey, with a brown-pink-grey matt surface, which shows minute particles of a specular material, which is probably mica.

Both of the rims illustrated (Fig. No. 2, (4) and (5)), belonged to large pots, about 6 inches in diameter across the mouth. In (4) the moulding seems to have been worked up out of the pot wall. In (5) the rim was tapered and flattened. Besides these, there is a fragment of the neck of a pot which was probably similar to one from the Oakhurst Shelter (OS. Fig. No. 1, and Fig. No. 2 (1)), but the lines on our example are all horizontal, and have a grooved effect as though they had been rubbed into the surface of the semi-dry clay.

Group II.—This group is represented by several fragments of a pink ware which has innumerable included fragments of a whitish material, the surface was finished matt and decorated with bands of purple colour which were painted on to the ware.

DISCUSSION.

There can be no doubt, but the pottery of our First Group is of a Hottentot facies, its resemblance to the Pella pot (HPPD), and the material from the Oakhurst Shelter, George (OS), is very striking.

The Second Group is so similar to some of the pottery in South African Museum, Cape Town, which was made by the Mbukushu of the Okovanango marshes, and to the painted ware which was found on the surface at Parma Kopje (M. Plate XXXV, 1 and 9), that all must be of a common origin.

The Pottery from the Mashowing River.

The Mashowing River is a tributary of the Kuroman; the pottery was collected at a point about 15 miles to the west of Battlemound Post Office.

Description of the Pottery.

Four pots are represented in this collection, a large deep bowl (Fig. No. 2 (3)), a Spherical Pot (Fig. No. 2 (6)), and a bowl in the painted ware. There is also the rim of a large pot the shape of which we could not determine. The rim, which was rounded and slightly everted, was in a coarse grey ware, which had been burnt to a brown-pink-grey matt surface.

The Deep Bowl (Fig. No. 2 (3)), was about 11½ inches over the rim. The clay was fine and black. and included many specks of mica. The rim was rounded and had a small roll on the outside. The surface was finished smooth, and appears to have been coloured grey with mica powder.

The Spherical Pot (Fig. No. 2 (6)), was about 8 inches over the rim, in a coarse light brown clay, finished to a smooth brown surface. The rim was rounded and slightly bevelled to the outside.

The Bowl in the painted ware (Fig. No. 2 (7) and (8)), which we have attempted to reconstruct from its fragments, was about 8 inches over the rim, 8¾ inches at its greatest diameter, and 3½ inches in depth. The clay was composed largely of small nodules of shale, and was brought to a light brown matt surface, which was finished on the outside with painted horizontal and vertical bands of purple colour, which included the hollow of the base. The rim was rounded and the hollow base was worked on to the bowl after the body had been formed.

DISCUSSION.

The Deep Bowl, the Spherical Pot and the rim fragment are so nearly featureless, that, beyond attributing them to a Bantu, rather than a Hottentot facies, there is little to be said for them. The Bowl, on the other hand, belongs very clearly to the painted ware which we have have already noted at Kheis and on the

Limpopo and the Okovango. It will be seen, therefore, that this pottery is to be included in our Second Group, which in our opinion it is all of Sotho origin.

The Pottery from Reids Drift.

Reids Drift is situated at the confluence of the Orange and the Zand Rivers, about 50 miles above Prieska. The pottery, which is very interesting, was collected from the Reids Drift Land Company's estate.

Description of the Pottery.

(i) A fragment of the rim of a pot which was probably about 6 inches over the mouth. The clay was a light grey and finished to a reddish burnished surface. The rim was rounded, the neck was slightly flared and decorated with shallow diagonal lines which appear to have been rubbed or pressed into a semi-dry clay, below these were at least two horizontal lines which had been made in a similar manner (Fig. No. 2 (9)).

(ii) Similar to the last, but the neck was thickened on the outside. Below the rim was a band of diagonal cross-hatching; it would appear that the colour had been put on the pot while it was still wet, and that the hatching was made with a blunt implement, which hardly marked the surface, except at the foot of the stroke, elsewhere it merely pressed the colour into the clay and made a dark line. Below the neck there were at least three shallow horizontal lines (Fig. No. 2 (10)).

(iii) Fragment of the rim of a pot about 5 inches in diameter. In a fine light grey clay finished to a rust-coloured matt surface. The rim was rounded and thickened on the outside, and the neck was decorated with irregular horizontal lines (Fig. No. 2 (11)).

(iv) Similar to the last, but the neck had a counter-hatched band which had been cut on the wet clay and the surface had been burnished (Fig. No. 2 (12)).

(v) Fragment of a rim in a fine light grey clay finished to a reddish brown matt surface. The rim had been rounded and decorated, small impressions made with a rough stylus at $\frac{3}{16}$in. centres.

(vi) Several fragments of a fine grey ware finished to a deep brown burnished surface, which had been decorated with lines of circular depressions, about $\frac{1}{8}$in. in diameter, at about $\frac{3}{16}$in. centres. These had been made in the same manner as the decoration of (i) above.

(vii) A fragment of a fine grey ware finished to a beautiful deep brown burnish and decorated with shallow lines and small dots.

(viii) A fragment of the rim of a Shallow Platter. The clay was brown and full of shale fragments. The underside of the platter was finished to a yellow matt surface, and the remainder was burnished with purple colour (Fig. No. 2 (13)).

(ix) A fragment of a spout in a coarse brown ware, the surface of which has been very much weathered.

Discussion.

This pottery also may be divided into two main groups; numbers (i), (ii), (iii), (vi) and (vii) belonging to the First Group; numbers (viii) and (ix) belonging to the Second, while (iv) and (v) seem to be intermediate.

The thickening of the necks which has been noted in the pottery from Oakhurst (OS. Fig 1, (3)) is very evident in this collection (Fig. No. 2 (10), (11) and (12)) as is the rust-coloured surface finish.

The grooved or rubbed line decoration has, so far as we are aware, never been described before, and the same applies to the rim decoration illustrated (Fig. No. 2 (10)). Both the decoration and the burnish of (vii) are of a very high order.

The ware of Fig. No. 2 (12) is identical with that of pieces which we have included in our First Group, but the decoration is entirely different to the rubbed lines which are so characteristic of the Hottentot pottery from this part of Bechuanaland, but as it is very similar to that which is found on Bantu pottery, we consider that this piece is intermediate between our two groups.

In the case of (v) the ware resembles Hottentot rather than Bantu pottery, but the decoration of the rim with stylus impressions has so far been recorded only from pottery of a Bantu facies.

The fragments included under (vi) belong to the same type of ware as (i) and (ii), and may indeed be parts of the same pots. The burnish is of a very good quality and has been carried into all the depressions of the design in a way which is quite new to us.

The fragment of the rim of a Platter (viii) belongs to the painted ware which has been described above. (Fig. No. 2 (13)).

The coarse ware of which the fragment of a spout (ix) was made leads us to believe that it is Bantu, but since spouts are known from both Hottentot and Bantu sites, we cannot be certain on this point.

Conclusions.

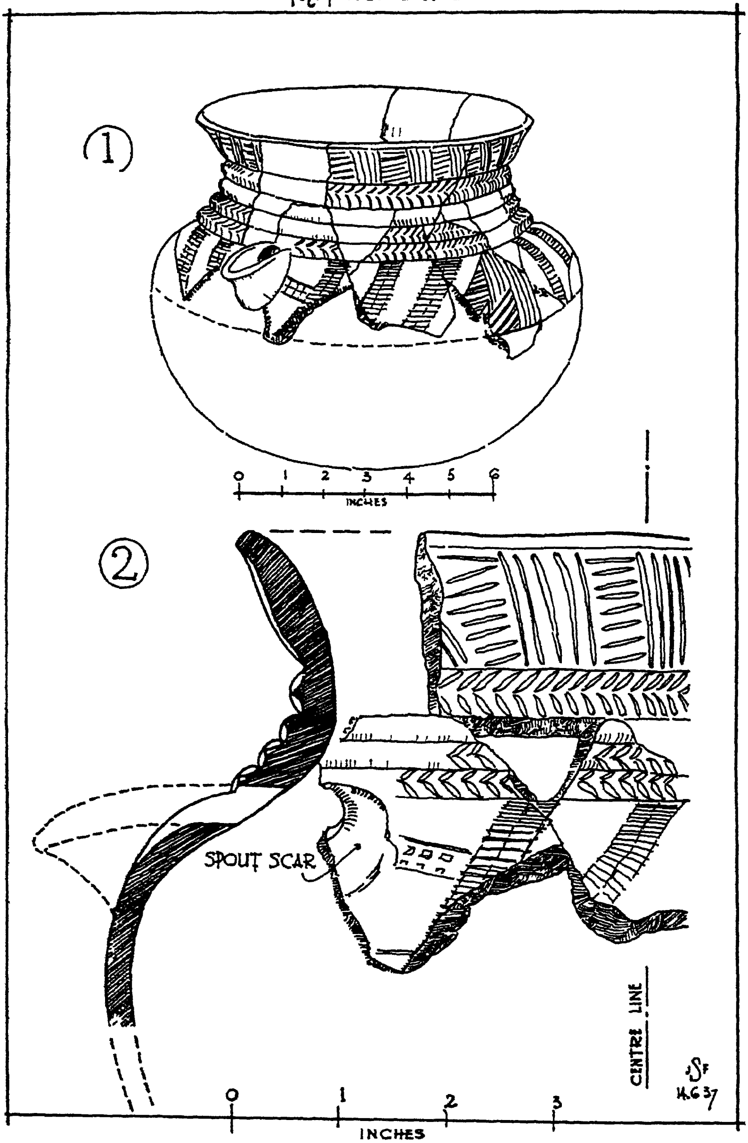
The importance of this pottery lies in the fact that we have before us examples of the prehistorical ceramics from a little frequented area of Bechuanaland.

This pottery can be classified as two groups. The First Group is of a Hottentot facies and includes examples from Reids Drift which show an unusual excellence of design and finish.

The Second Group, can, with equal certainty, be assigned to the Bantu, and with great probability to one of the Sotho

tribe for the painted pottery, to which the most distinctive types of this group belong, can be definitely associated with those people

TEXT FIGURE No3



In addition to these principal groups, several pieces of pottery seem to combine Hottentot with Bantu features. Such wares have not been described previously from Bechuanaland, but they are entirely consistent with what little we know of the history of this debatable land during the latter part of the 18th century.

(7) *Pottery from the Karibib District of South-west Africa.*

This pottery was collected by Mr. H. W. Bell Marley of Durban from the Farm Keets, which is 20 miles from Karibib It was found lying in a hearth, 18 inches in diameter, which had been formed with a circle of stones.

Description of the Pottery.—This pottery all forms part of a Spherical Shouldered Pot, $10\frac{1}{4}$ inches over the rim, about $14\frac{3}{4}$ inches in diameter, and about $10\frac{1}{2}$ inches in height. The clay was of a light grey colour, very gritty and finished with a smoothed surface. The rim was rounded, flattened and slightly burred on the outside. Directly below the rim the neck was decorated with an irregular line of vertical impressions, below which there was a shallow line, all having been made on the wet clay. At a distance of $1\frac{1}{2}$ inches below the rim a round hole $\frac{5}{16}$ inches in diameter was pierced from the outside before the pot was baked.

DISCUSSION.

This pottery shows no particular similarity to any of the Hottentot wares with which we are acquainted, and on the whole it resembles pottery of a Bantu facies. The practice of piercing the rim was noticed in several pieces from Mapungubwe (M. Plates XXIII 23, XXIV 5 and XXV 4), to which this pottery may be related

NOTES ON OTHER ARCHÆOLOGICAL MATERIAL FROM BECHUANALAND.

(1) *Beads.*

As we have previously remarked, all the Archæological material, including the pottery from the Bechuanaland sites, was found on the surface, and the different pieces may have no other association than that of propinquity, nevertheless, Mr. Swan's views are well worthy of being recorded:—

"Some of the fragments of pottery and the beads from Prieska and Reids Drift would appear to be associated with the larger, and later, ostrich shell beads, and the rougher and later microliths."

The beads mentioned above were not very distinctive, the one from Prieska is of black wound glass. A mottled bead from Reids Drift was an irregular bicone, 7 x 8·5 mm., made of a cream-coloured wound glass into which blobs of light blue glass had been incorporated during manufacture. We consider that the first of these beads was imported from the Cape, and that

they may be provisionally dated as being subsequent to circa 1790. The second, is called by the natives "Traina," and can be no older than the advent of the railway.

One of the bead fragments from Klipfontein is of far greater importance. It is of a light blue glass streaked with a chalky substance. This bead was unquestionably produced by the same process as that by which the so-called "Garden Roller" beads from Bambandyanalo were made. (M. Plate XXXIX 5 and p. 112, and UBSR. p. 414, Fig. 1, 4).

Engraved Ostrich Egg-shell.

The fragments of engraved ostrich egg-shell from Stone Hills offer an interesting parallel to some of the engraved pottery from Bambandyanalo (M. Plates XXIV 5 and XXVIII 11), and it may well be that these practices are closely allied.

Description of the Illustrations.

Text Figure No. 1.

(1) Three Pots from Glenwood High School, Durban. Class NC_2a.

(2) A fragment of a large Beaker-bowl from near Mapumulo. Probably Class NC_2a.

(2) A fragment of a large Beaker Bowl from near Mapumulo. Probably belonged to it.

(3) A Spherical Shouldered Pot from the Karibib District of South-west Africa.

(4) Fragment of a Pot from Uqupu.

Text Figure No. 2.

(1) and (2) An unusual Pot from 127, Sydenham Road, Durban. Class NC_2a.

(3) A Deep Bowl, 11¼ inches over the rim, from the Mashowing River.

(4) Fragment of a rim from Kheis.

(5) Fragment of a rim from Kheis.

(6) Fragment of the rim of a Spherical Pot, from the Mashowing River.

(7) and (8) A Bowl in the Painted Ware from the Mashowing River.

(9) A rim fragment from Reids Drift.

(10) A rim fragment from Reids Drift.

(11) A rim fragment from Reids Drift.

(12) A rim fragment from Reids Drift.

(13) A fragment of the rim of a Shallow Platter, from Reids Drift.

Text Figure No. 3.

(1) A proposed restoration of the Spouted Pot from Weenen Commonage. Class NC_3

(2) A detail of the section and decoration of this Pot.

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A CONTRIBUTION TO THE PHYSICAL ANTHROPOLOGY OF THE NAMA HOTTENTOT

BY

L. H. WELLS,

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Read 6 July, 1938.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 396-398, December, 1938*

THE MU-TSUKU

BY

LOUIS C. THOMPSON,

Copper Mines, Messina, Transvaal.

With 1 Photograph.

Read 8 July, 1938.

Mu-Tsuku is the name given to two types of copper ingots by the Ba-Lemba Ba-Venda and Ba-Suto people who live near the old copper workings on both sides of the Limpopo River in the Northern Transvaal and Southern Rhodesia. They were made originally by the Semitic Ba-Lemba miners, and were copied much later by the Ba-Venda and Ba-Suto miners.

The word Mu-Tsuku is used when speaking of copper by the members of the Semitic Ba-Lemba tribe, whose ancestors were the early miners of the copper lodes, which are situated near the Limpopo River. In the Chicaranga language Tsuku means red. At a late date the Ba-Lemba taught the Si-Venda and Se-Suto speaking peoples how to mine and smelt copper. The Se-Suto and Si-Venda word for copper is Mesina.

There are two types of ingots (a) *Commercial* (b) *Ceremonial*.

(a) The *commercial* ingots vary in shape, the smaller ones being cylindrical, and the larger ones rectangular. The top of the ingot is decorated with studs; the number of studs indicated the amount of copper in the ingot; each stud represents approximately ¼ lb. of copper. One stud represented the value of an iron hoe, two hoes equalled one goat, ten goats equalled one cow. When money came into use, an iron hoe was worth 5s.

The ingots were used for barter; the copper being made into beads, wire for bracelets—anklets, bangles, etc. The ingots vary in size, a small one with thirteen studs (base missing) weighs 3 lbs. 1 oz. A large one was so heavy that it required the strength of two men to lift it.

The weights of this type of ingot found near Messina are as follows:—

13 studs on top, in three rows (base missing):
3 lbs. 1 oz.

15 studs on top, in three rows (base missing):
3 lbs. 5 oz.

28 studs on top, in four rows:
6 lbs. 14 oz.

38 studs on top, in four rows:
10 lbs. 3 oz.

40 studs on top, in four rows:
10 lbs.

These ingots are very rare.

(b) The *ceremonial* ingot differs from the commercial ingot in that the studs on the top are larger; the interior of the body is hollow, the body being composed of a thin layer of copper, the bases are much broader. They vary slightly in size and in the number of studs on the top.

Ceremonial Ingots.

The old natives will not divulge the purpose for which this ingot was made; it probably had a ceremonial use. Two graves have been found near the South bank of the Limpopo River which were decorated with these ingots; on one grave were six ingots and on the other two ingots.

The ingot was cast in a mould composed of damp sand. The appliances used were:

(a) Wooden forms of various sizes which shaped the mould.

(b) A piece of wood similar to a paper knife to draw lines in the sand, so that the rows of studs should be equidistant apart.

(c) A piece of wood shaped like a small pencil, to make holes in the mould for the studs.

After the copper had been removed from the furnace, it was melted in a thick clay pot. The size of the wooden form was then chosen, according to the amount of copper in the pot; with this the mould was made.

The commercial ingot was made in three castings. In the case of the ceremonial ingot the head was cast first, then a piece of clay was placed in the mould, leaving sufficient space all round, so that the thin wall of the body could be cast; the base was formed by the overflow of the copper; in many specimens the base has been strengthened by the addition of a further layer of copper.

The ingots were made up to the early sixties of the last century, when Ramabulana, the Ba-Venda chief instructed his head-man Mesina Ba-Leya who was in charge of the copper mines to close down.

This information was obtained by my wife, without the aid of an interpreter from very old natives living in the Northern Transvaal and Southern Rhodesia. Her chief informant is an old man named Makushu Ba-Dau, whose mother was the daughter of Mesina Ba-Leya, who was in charge of the copper mines near Messina during the reign of the Ba-Venda chief Ramabulana. As a small boy he helped his grandfather with his mining operations.

Although he is now a very old man, whose probable age is ninety years, his mind is very clear with regard to the mining methods of the old miners. He is one of the few so-called "Ancient" copper miners alive to-day. Two years ago he demonstrated to my wife and me how the ingots were made.

South African Journal of Science, *Vol. XXXV, pp. 399-406, December, 1938.*

EXCAVATIONS IN A PIT-CIRCLE AT INYANGA, SOUTHERN RHODESIA

BY

C. H. E. Fripp,

Bulawayo, S. Rhodesia,

with a Report on Relics found during the Excavations

BY

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Junior Lecturer in Anatomy, University of the Witwatersrand, Johannesburg.

With 3 Text Figures.

Read 8 July, 1938.

Introduction.

The Inyanga area on the eastern border of Southern Rhodesia is characterised by the occurrence of stone structures of a character decidedly different from that of those found in other parts of Rhodesia. They include hill-top fortifications, agricultural terraces and " pit-circles," structures consisting of a stone-walled pit entered by a tunnel, and surrounded by a levelled platform bearing hut-foundations. These remains were briefly described by Randall MacIver in 1906, and played a considerable part in his subsequent controversy with R. N. Hall, but since that time very little additional work has been done on them.

Within the last few years " pit-circles " similar to those of Inyanga, have been described from the Penhalonga area, slightly further to the south. These have been studied by Gwatkin (1932-33), Mason (1933) and Mrs. Martin (1936). While these observers had shown the general correspondence of the Penhalonga and Inyanga structures, certain apparent divergences in their architecture had been noted. Moreover, doubts existed as to the relation between the types of pottery found on various types of site at Inyanga and the Niekerk ruins and that from the Penhalonga " pit-circles."

In the hope of clarifying some of these problems, Mrs. Martin in 1937 cleared the main hut circle of one of the "pit-circles " (designated by the number 16A) at Inyanga itself. This excavation, in which she very kindly allowed me to assist her, yielded a number of pot-sherds which appeared to correspond with the type found in the " pit-circles " of Penhalonga. The material

was, however, scanty and fragmentary, and Mrs. Martin was desirous of increasing it by a further excavation. As circumstances did not permit of her carrying out this personally, she suggested that I should do so. In accordance with this arrangement, which was retrospectively approved by Mr. Neville Jones, Director of the Rhodesian Government Bureau of Archaeology, I carried out during the first two weeks of November, 1937, the excavation which is described in this report. I was assisted in this excavation by an intelligent native who had assisted Mrs Martin in several previous excavations.

DESCRIPTION OF THE EXCAVATIONS.

The site selected for the work was a dilapidated pit-circle designated No. 16B. This structure is situated about 400 yards E. by N. of the position occupied in 1937 by the Rhodes Inyanga Estate rest hut, and about 600 yards N.-W. of the pit-circle No 16A, previously excavated. It lies practically on the crest of the north-facing slope of the ridge which lies between the Mare and the Inyangombi Rivers.

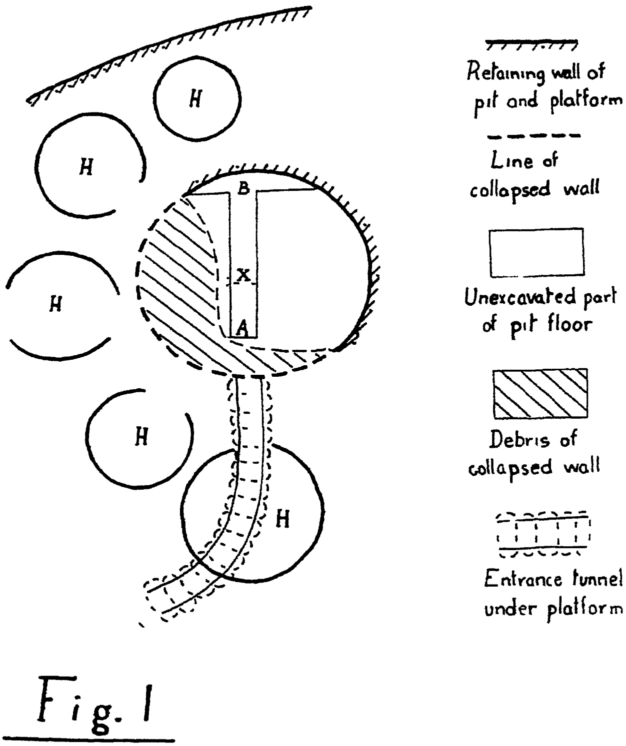

FIG. 1.—Plan of part of pit-circle No. 16B, Inyanga. A-B, area of excavation; X, limit of later (cobbled) floor, HH, foundations of hut-circles. Scale ⅛in.: 1 foot.

Fig. 1 shows the general plan of this pit-circle, which reveals all the essential features of this type of structure as described by MacIver and by Mason. It will be seen that the wall of the central pit is partly collapsed, while the surrounding hut-circles are ruinous, and their relation to the pit can be indicated only approximately.

The excavation consisted of a trench, two feet wide and fourteen feet long, traversing the pit from North to South and carried through the floor to undisturbed sub-soil. At its northern end the trench abutted against the north (down-hill) wall of the pit, but at its other extremity it fell slightly short of the southern wall owing to the ruinous condition of the latter.

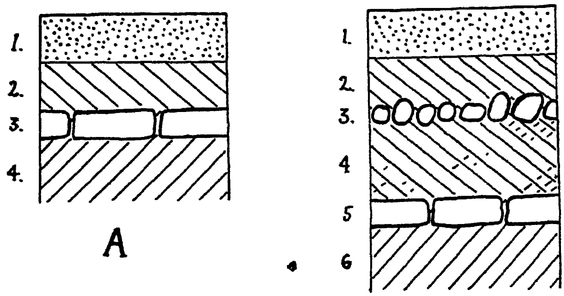

Fig. 2

Fig. 2.—A, Section of deposits at A, Fig. 1. 1, leaf-mould; 2, grey soil; 3, flagged pavement; 4, red clay subsoil.
B, Section of deposits at B, Fig. 1. 1, leaf-mould; 2, grey soil; 3, cobbled pavement; 4, grey soil with pockets of red soil; 5, flagged pavement; 6 red clay subsoil. Scale, ¼in.: 1 foot.

Fig. 2A shows the profile of the deposits at the upper extremity of the trench. On the surface was a layer of leaf-mould, three to six inches in depth, and below this a layer, about six inches deep, of brownish-grey soil containing pot-sherds. Beneath this was a regular and well-laid paving of medium-sized flat stones. This was laid on a slope of approximately 1 in 10, and rested on and was partly bedded in the sterile red clay sub-soil.

At the lower extremity of the trench the deposits, which are illustrated in Fig. 2B, were more complex. This resulted from the presence of an additional paved, or rather cobbled, floor at a higher level than the original flagging. The extra floor extended over the down-hill half of the excavation. At its upper margin it was in contact with the lower, flagged floor, but as it was laid with only a very slight slope, the two became separated by a wedge-shaped interval as they approached the wall on the

down-hill side. This interval was occupied by a layer of brownish-grey soil with pockets of red soil. The upper floor was composed of rounded, apparently waterworn, stones and was very roughly and irregularly laid, some of the stones standing as much as three inches above the general level. It was covered by the same layers. leafmould above the brownish-grey soil below, as overlay the lower floor in the up-hill half of the trench.

The excavation was extended for some feet on either side of the original trench along the pit wall on the down-hill side. In this section of the wall it was anticipated from Mason's account that a drain opening would be found, but no such structure was exposed. Careful examination, however, revealed the presence of a straight bond in the wall in the position which the drain opening should have occupied; it appeared that this part of the wall had been rather indifferently reconstructed.

That a drain had originally existed in this situation appears an almost certain inference from the steep slope of the original floor. Mason has pointed out that this slope with a drain at its lowest point appears to have formed part of a carefully devised mechanism for the cleansing of the pits. It seems, therefore, that the drain opening must have been abolished at the time when the wall was reconstructed. This again, is probably to be correlated with the levelling and repaving of the pit floor, which would in any case have covered up and rendered useless the drain opening. Conclusive evidence could, however, only be obtained by excavation in the platform beyond this wall in search of remains of the drain channel. For such work neither the time nor the facilities were at my disposal. There is, however, ample evidence of a considerable drainage trench, outside the platform of the pit, on its lower-side.

The relics found during the excavation, which consisted almost entirely of potsherds, have been examined by Dr. L. H. Wells, whose report on them is appended to this paper.

Discussion.

This investigation has perhaps contributed to the solution of some of the problems raised by these structures; it has certainly raised a number of new ones. The primary aim of obtaining a satisfactory collection of pottery for comparison with that from the Penhalonga pits has been fulfilled. From Dr. Wells' examination of this material, the conclusion appears warranted that the domestic pottery of the Inyanga pit-circles was identical with that found in those of Penhalonga. There is, however, the possibility of a further, intrusive element, represented by the black graphite-burnished pottery.

From the structural point of veiw, the excavation has revealed clear evidence of considerable remodelling of this particular pit-circle. The original steeply sloping flagged floor had been levelled by an earth fill and cobbled floor, while. probably

in correlation with this, the pit wall was reconstructed and the drain opening apparently obliterated.

In the light of Mason's observations on the carefully planned drainage arrangements of the pits, these changes strongly suggest a considerable change in the manner in which this pit was utilised. The fact that sherds of typical pit-circle pottery were found in the deposits overlying the later, cobbled floor seems further to indicate that the changes were introduced by people of the same culture as the original pit-builders. This construction cannot therefore be compared with the blocking of hut-circle entrance passages by burials, recorded by Mrs. Martin at Penhalonga, for these burials were almost certainly made after the site had ceased to be inhabited.

The question then arises whether this change of design represents the idiosyncrasy of the inhabitants of a single site or a widespread change of usage. To determine this the excavation of a large number of sites would be necessary. In this connection it may be observed that Mason has expressed surprise at Hall's failure to notice the existence of drains in the pit-circles. If it should prove that a large number of the pits have been reconstructed in the manner of the specimen excavated by me, this omission would be explained.

It is at all events clear that for the full solution of the many problems connected with these sites, investigation on a scale much larger than hitherto is essential. The results of this small excavation and those obtained by Mrs. Martin at Penhalonga have revealed how complex may be the history of a single site. Before any generalisation can be made from such observations, they must be extended to a large number of sites over the whole area of this peculiar culture. This work is far beyond the resources of the small group of enthusiastic workers now engaged in this field. Organised research on a large scale is clearly demanded. If this is at present impracticable, it is essential at least that some organised plan of campaign be prepared, so that such individual efforts as can be made are directed to the best advantage.

Summary of Conclusions.

1. Excavation in the central pit of a pit-circle at Inyanga has revealed evidence of considerable reconstruction, the floor having been levelled and re-paved, the wall partially rebuilt and the opening of the drain apparently obliterated.

2. Pottery, described in a report appended to this paper, proves to be for the most part identical with similar material from the pit-circles of Penhalonga, though a possible foreign element (black graphite-burnished ware) is also present.

3. These observations, furnishing further evidence of the complex history of these sites, demonstrate the necessity for the investigation of this culture on a much more extensive scale than hitherto.

ACKNOWLEDGMENTS.

I wish to express my indebtedness to Mrs. C. E. H. Martin for the practical instruction in excavation methods which enabled me to carry out this investigation and for her constant help and encouragement, to Mr. R. Finlay (Forestry Division) and Mr. Purdon (Resident Forester, Rhodes Inyanga Estate) for local permission to undertake this work, and to Mr. Neville Jones for confirming this arrangement, to Dr. L. H. Wells and Dr. A. Y. Mason for examining and commenting on my "finds" and notes, and to Professor R. A. Dart for his helpful suggestions during the preparation of this paper.

REPORT ON RELICS FOUND DURING THE EXCAVATION.

Mr. C. H. E. Fripp has very kindly allowed me to examine the relics found by him in the course of his excavations in the pit-circle No. 16B at Inyanga. These comprise in addition to a fragment of animal bone and part of the molar tooth of a large ungulate, two stone objects showing evidence of utilisation by man and a large number of potsherds.

Stone Artefacts.—Of the utilised stones one is a rounded quartz pebble, about 6 cms. in diameter, which shows clear signs of use for grinding or polishing.

The other, more problematical in its nature, is a flat, triangular fragment of brownish ochreous material measuring about 6 x 4ins. with a thickness of 15-20 mm. The material has been identified by Miss M. E. H. Welsh of the Department of Geology in this University as a clay containing a large quantity of hydrated ferric oxide. This fragment has been artificially perforated. On one face, two conical holes, about 5 mm. in diameter at the surface with an interval of 3 mm. between them, have been drilled. One of these ends blindly at a depth of about 10 mm.; the other intersects a figure-eight aperture on the other face formed by two intersecting openings each about 3 mm. in diameter. Professor C. van Riet Lowe has very kindly examined this fragment and confirmed the artificial nature of the perforations.

Pottery.—More than fifty sherds of varying size are included in the collection. These include portions of some dozen rims, of which nine are sufficiently large to permit of accurate delineation (Fig. 3).

In texture all the sherds confirm to a single type. They are of a reddish-brown clay containing small angular particles of quartz. The firing has caused the particles to cohere, but without any fusion of the constituents and has modified the colour of a thin superficial layer. The sherds are characteristically thin or of medium thickness, many being only 5 mm. thick.

Both in form and in surface finish, there is considerable variety among these specimens. With two exceptions, the sherds have a grey or buff surface with either a smooth or a

matt finish (Schofield 1937). The pieces thus finished range in form from a deep bowl type with everted rim (Fig. 3A) through intermediate forms (Fig. 3B, C) to a wide-mouthed pot with a low neck of concave profile (Fig. 3D-G).

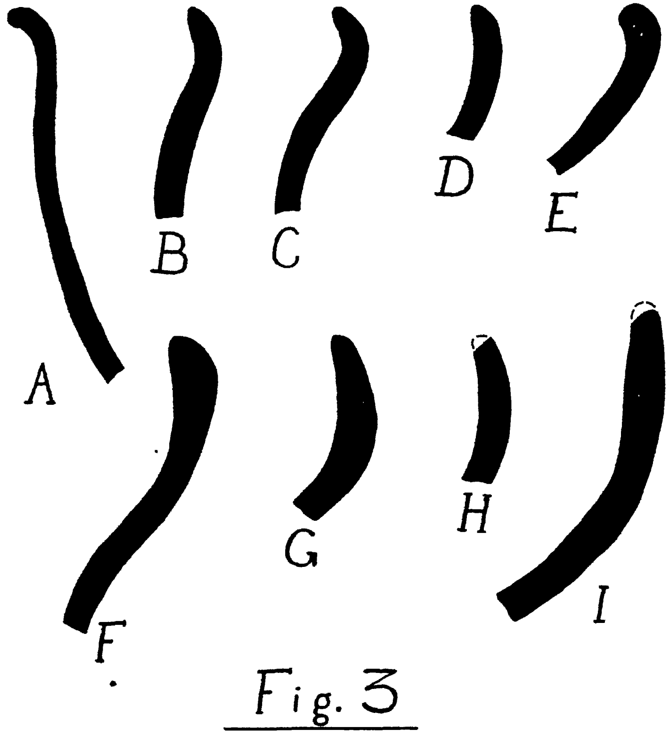

Fig. 3.—Profiles of pottery rims from the excavation. A, grey smooth surface, mouth diameter 23 cm.; B, grey-buff smooth surface, mouth diameter 26 mm.; C. buff smooth surface, mouth diameter 15 cm.; D, grey smooth surface, mouth diameter 21 cm.; E. buff matt surface, mouth diameter 19 cm.; F, grey smooth surface, mouth diameter 23 cm.; G, grey matt surface, mouth diameter 18 cm.; H, light brown burnished surface, mouth diameter 16 cm.; I, black graphite burnished surface, mouth diameter 10 cm. Half natural size.

Of the exceptional pieces, one is the rim of a wide-mouthed pot of quite typical form (Fig. 3H) which is finished with a light-brown burnish. The other is unusual in its form, being a pot with a much taller and narrower neck than any other specimen in the collection (Fig. 3 I), and also in being finished with a graphite burnish.

I have been able to compare these sherds with those collected and described by Mason (1933) from the Penhalonga pit-circles, and also with specimens collected from that area by

Mrs. Martin. The unburnished sherds from Inyanga agree remarkably closely in texture, surface finish and form with the typical material from Penhalonga. It appears, therefore, that the inhabitants of the pit-circles of Inyanga and Penhalonga, possessed a common type of domestic pottery. The brown burnished piece also possesses a counterpart in sherds with a honey-coloured burnish found by Mason, and similar material obtained by Mrs. Martin. This ware is evidently a more highly finished variety of the typical pit-circle pottery.

The graphite-burnished sherd, on the other hand, appears exceptional both in form and finish. The material from Penhalonga affords no parallel to the tall narrow neck of this vessel. Mrs. Martin has found a few graphite-burnished fragments at Penhalonga; these, however, occurred near the surface in a hut-circle which appeared to have been reconstructed. This ware thus appears to be an intrusion, and seemingly a late intrusion, in the pit-circle culture.

This excavation has afforded no decorated material comparable to that described from the Niekerk area by MacIver (1906). The relation of this ware to that of the Penhalonga and Inyanga pit-circles remains obscure. It may, however, be taken as established that the domestic pottery of the pit-circles in these two areas is of identical character.

It appears, therefore, that we are justified in associating a characteristic type of domestic pottery with the equally characteristic pit-circle architecture. The occurrence, both at Inyanga and at Penhalonga, of apparently different and intrusive pottery, and the possible relation between this and reconstruction of the stone structures, presents a further problem as yet unsolved. Both this and the debated question of the relationships of the Niekerk pottery afford evidence of the necessity of the extensive and co-ordinated research in this area advocated by Mr. Fripp.

I wish to express my thanks to Mr. Fripp for the opportunity of examining this material, to Mrs. Martin for the loan of material for comparison, and to Professor C. van Riet Lowe and Miss M. E. H. Welsh for their comments on one of the specimens.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 407-411, December, 1938.*

A SCIENTIFIC SYLLABUS OF PHYSICAL EXERCISES FOR SMALL CHILDREN

BY

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Read 5 July, 1938.

ABSTRACT.

This paper, which has been very considerably shortened because of lack of space for publication, was read in conjunction with the demonstration of the first South African made film on Physical Education. The author also showed a collection of 328 photographs, sketches and titles to illustrate his subject. The film is now available from the Film Bureau of the Union Department of Education.

PSYCHOLOGICAL BASIS.

A purely phenomenological approach to the problem of teaching physical exercises to small children shows, as one of the most striking features found in the young child, its tendency to indulge in rather purposeless motor activities which are commonly described as " play." This complex feature, which has often been stated to be characteristic of childhood, but which is also found in animals and in primitive human races, has been most excellently analysed in a recent monograph by Buytendijk. This writer stresses the lack of purpose which speaks out of all motor expressions of the young child, the absence of a distinct direction, of aims and intentions in its actions. There is no conscious or consciously supervised co-ordination of movements. The latter feature is so impressive that we unknowingly conclude from lack of aimful co-ordination alone that an individual is "young": a grown-up dog seems to be young when he sits with one leg rotated or with the one ear standing and the other hanging.

PATHIC AND GNOSTIC.

E. Strauss has distinguished between two kinds of relationships between individual and environment. The one he calls the " pathic " and the other the " gnostic " attitude. Pathic actually means " being swept or carried away," while gnostic means a non-emotional attitude which aims at facts, at concrete things and at distinct experiences.

Strauss' terminology is of value to our problem because it obviously refers to the essential difference of attitude towards life in general as well as especially towards physical exercise as found in youths and in adults. " From the earliest days in the life of a human being," Pear says, " instincts and habits shade gradually into each other. One reason for this being that dominant habits are usually formed along the lines of some powerful instinct." The young individual lives in a predominantly pathetic sphere, as long as instincts are the dominant factors, and habits their visible manifestations. When, at a later stage of individual development, habits are formed under other influences than only those of instincts, the gnostic phase of life sets in. To the young child environment is a strange complex. It is necessarily " a-gnostic " towards its outer world. It simply cannot develop a gnostic attitude before a lasting relationship between itself and the world has been established. This attitude is responsible for the often stressed "naivity " of the child, the last term actually referring to the impressive aimlessness and lack of purpose of its actions.

Development and Education.

In the course of normal human development a change is effected which one can characterise by saying that the individual passes from the pathic into the gnostic world. Development, which is consciously supported by educational measures, on the one hand elevates the individual to a higher level of efficiency—physical as well as otherwise—but on the other hand, tends to split the formerly "total" personality into two spheres—that of the mind and that of the body. It is that division which ultimately enables us to distinguish sharply between " abstract " and " concrete." That this gulf, which is opened during the process of development, can be bridged over has been emphasised by Buytendijk: the artist and the player, the dancer and the " mentally disordered," the pious and the ecstatic can again reach the " pathic " totality of experience which the young child enjoys, although in the majority of cases, only temporarily.

Expression and Purpose.

It is not only intellect and character, but also the motor element of each individual that is shaped and changed during the above period of development. One can, generally speaking, divide movements into two big groups: into expressive and into purposeful movements. The former serve to express primitive, instinctively guided, emotionally influenced experiences. They are therefore always individual manifestations. "The free skater who has composed his own programme is like a poet reciting his own poetry. Individuality can be expressed in the choice of words or curves, their pronunciation, or execution, and their arrangement." (Pear).

Purposeful movements follow a distinct aim. They are necessarily unindividual, " collective " and applicable to

practically every number of performers in the same way and at the same time. They not only do not demand individuality, but they actually demand the suppression of individual motor tendencies in order not to clash with the exactitude of the performance.

Practical Application.

How can one induce small children, when they are just beginning to sense the world of concrete tasks and distinct aims, to carry out a syllabus of pre-arranged exercises?

It was decided to make use of a property of young children, the educational significance of which was stressed to the author many years ago by Professor Adalbert Czerny: the ability of the child to identify itself with practically everything in which it has taken an emotional interest. The child can make itself experience the dynamic of a railway train by pulling on a string behind itself meaningless things. Such a representative act elicits all the feelings which would be evoked by the imagined symbol itself. If the psychic equivalent to the movement is absent, the muscular action of the child becomes a sort of circus performance. " A chimpanzee may be taught to open the door for a lady, but, presumptuous as it may be to prescribe the limitations of the simian mind, few would hold that any very potent sentiment of chivalry need form the background of his action." (Pear). The criterion for the "pathic" value of a child's "exercise " is whether it reaches, in the course of its action, a high degree of emotional satisfaction, which also induces the child to repeat its games until it is tired or exhausted. Sigmund Freud has drawn attention to and analysed the tendency of children to repeat their games and actions. I have deliberately made use of this phenomenon in our syllabus of exercises. The ability of de-personalisation and of self-identification of children, upon which the whole syllabus as depicted in our film is based is actually part of the " pathic " attitude of the child.

Conditions and Inducements.

Buytendijk has stressed that the play tendency of children manifests itself only under certain conditions which, of course, must be known if one wishes to induce children to carry out definite exercises. As far as we are aware, no experiments had hitherto been conducted to find out what these conditions actually are. We therefore decided to make systematic observations ourselves.

Experiments and Observations.

Our own experiments, which were based on teaching practise extending over a period of twelve years, were ultimately carried out on a group of about fifty children between two-and-a-half and seven years of age.

Methods.

Among the various methods tried far the best was that of actually showing the children "moving symbols." Often, it was

sufficient if the teacher pretended to be the symbol herself. But the demonstration of the real symbols, i.e. of animals, toys, workers, etc., or—equally effective—of their movie picture, induced the children most strongly to do the desired exercises. In fact, it was not difficult to make the children identify themselves with the symbols.

The experiments, which were carried out during the weeks preceding the taking of the actual film pictures, made it clear that the best way to elaborate a scientific syllabus of exercises for small children would be to collect systematically a number of suitable symbols, the imitation of which would demand of the children to carry out all movements which are to be included in a modern scheme of muscular training.

The Syllabus.

We therefore collected the symbols in a way that the children were induced to do exercises which necessitate the use of all the main groups of muscles, such as:

1. Of the head and neck (ex. "The Seal"). 2. Of the arms (ex. "The Boxer"). 3. Of the chest (ex. "The Balloon"). 4. Of the lateral trunk (ex. "The Metronome"). 5. Of the abdomen (ex. "Rowing"). 6. Of the back (ex. "Rocking-horse and See-saw"). 7. Of the legs (ex. "Kangaroo"). 8. Of the feet (ex. "Giants and Dwarfs").

Attention was given to the inclusion of exercises demanding strength (ex. "Carrying the Logs" and "Wheelbarrow") and endurance (ex. "Dog Race"). Stretching (ex. "The Tall Tree") and bending (ex. "The Drooping Tree") exercises occurred in almost every lesson.

The Film.

The scenario of the movie film was elaborated by the author. He also conducted the photography of most of the symbols, which necessitated visits to toy-shops, zoos, air-displays, children's playgrounds; factories and other places. He made sketches for the title pictures; directed the photography of the actual exercises; supervised the cutting of the various scenes for the final film reel, deciding which movements had to be included and which not. He wrote and adapted the commentary and directed the synchronisation operations. As most of the symbolic activities chosen for the syllabus are of a rhythmical nature, it seemed to be advisable to have the sound film accompanied by music. "Where time-values can be expressed objectively," Pear says, "as when the movement is performed to music, learning for most persons is much easier. . . . . Rhythm, too, is obviously a valuable help in forming co-ordinations, provided that their elementary constituents are known." The author, therefore, in collaboration with a professional musician, prepared a musical programme to accompany the film.

In fact, a distinct increase was noticed in the impressiveness of the film on children and audiences to which it was shown at the various stages of its production after the musical part had been added.

The picture scenes of the actual exercises were taken without detailed rehearsals. In this way a considerable degree of spontaneity was attained, admittedly at the expense of what a drill-master of the older school might have called " exactitude," which however was not the goal.

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GROWTH IN EUROPEAN BOYS IN INSTITUTIONS: A STUDY OF FIVE DIMENSIONS IN 446 CASES

BY

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Read 8 July, 1938.

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A COMPARATIVE STUDY OF EUROPEAN AND NON-EUROPEAN DIFFERENCES IN RACE PREFERENCES

BY

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Read 7 July, 1938.

ABSTRACT.

In this brief contribution, I wish to report upon the differences in race preferences of two European groups and two Non-European groups. the former made up of English and Afrikaans-speaking South Africans and the latter of Cape Coloured and Indians.

It is obvious that for a meaningful comparison to be made between the race preferences of different groups. it is highly desirable to have the preferences expressed in a quantitative form and most desirable to have the quantitative differences between any two preferences expressed in terms of the same common unit. The technique required for this purpose has been worked out independently by L. L. Thurstone. " An Experimental Study of Nationality Preferences," *Journal of General Psychology*, Vol. I, 1928, pp. 405-425, and J. P. Guilford, " The Method of Paired Comparisons as a Psychometric Method," *Psychological Review*, Vol. 35, 1928, pp. 494-506, and consists of an adaptation of the familiar psychophysical method of paired comparisons in which " a group of observers is used instead of a single observer and in whch each member of the group makes only one discriminatory judgment for each possible pair of stimuli in the stimulus series." (Thurstone, op.cit.p.405). Instead of using the traditional stimuli of lifted weights and asking the subject to respond to the situation: " Which of these two weights is the heavier?" We place before the subject a pair of races, nationalities or groups and ask him to say which of the two he would rather associate with or, more simply, which of the two he prefers (often enough, a choice between two evils!).

From the results we can then obtain the average percentage of preferences for each of the items or " stimuli " in the list of races, nationalities or groups under investigation and find by reference to a table of the normal probability function, the

distance on the abscissa or baseline, in terms of the probable error of the distribution as unit, of the difference between this average percentage and the mean or 50th percentage of the normal probability curve.

The races, nationalities or groups which played the role of stimuli in this study were the same as those that appear in the author's Social Distance Questionnaire (*vide* Race Attitudes in South Africa, Chap. X). There are twelve of them and each subject who took the test on race preferences or the Racial Preferences Inventory, was called upon to make 66 comparisons and express 66 preferences so that each race, nationality or group could be paired with, and preferred to, every one of the other members of the whole set.

The instructions at the top of the Inventory read as follows: "This is an experimental study of racial or nationality preferences. You are being asked to underline in each pair the one race, or nationality, you prefer or that you would rather associate with. For example, in the pair: Chinese-Japanese, if you prefer Chinese to Japanese, underline *Chinese*; if you prefer Japanese, underline *Japanese*.

Note: Be sure to underline only one in each pair even if you have to guess, and do not omit any pair.

Note on Reliability.

The psychophysical method of paired comparisons is generally recognised as being the most reliable as well as the most thorough and exhaustive of all the various psychophysical methods of classical experimental psychology. But when, as in the present case, we are not making use of physical stimuli which can be related to a physical or objective scale but of what may be described as "psychological stimuli" which must be distinguished on the basis of degree of subjective preference and which, as such, cannot be related to any objective standard, we naturally require some assurance that the results obtained are consistent or that they can be relied upon to remain constant should the test be repeated on the same or similar groups. For the purpose of determining the degree of reliability, one group of 80 Afrikaans-speaking subjects was divided into two halves and the results correlated by the product-moment method. The coefficient of correlation was ·998.

Note on Validity.

The validity of the method is less easy to determine in any strict quantitative way. But considerations such as the agreement between the order of preference for the various races, nationalities or groups as determined by the instrument and the order of preference as reflected by social tradition and by social practice seem to suggest that the Racial Preferences

Inventory does actually measure what it purports to measure, namely, the existing racial preferences of different groups. Another consideration is the very close agreement between the results obtained by the Social Distance Questionnaire mentioned above and this Inventory both of which place the various races, nationalities or groups in exactly the same order relative to one another for those groups who had taken both the Inventory and the Questionnaire.

Finally, if the position of the Natives on the "preference scale" for different groups is compared with the attitude towards the Native of those same groups as measured by the author's Scale for measuring Attitude towards the Native (op. cit. Chap. IX), we find significant variations in both sets of values. Thus, for example, if we take the results, which are given below, obtained from the Cape Coloured and the Indian groups, we find that there is a marked difference in the order of preference assigned to Natives by these two groups. You will notice that for the Cape Coloured group the preference value assigned to Natives is $-\cdot50$ P.E. while for the Indian group the preference value assigned is $-\cdot10$ P.E. Natives as a race (or group) occupy an appreciably higher or more favourable position in order of preference for the Indian as compared with the Cape Coloured group.* When the attitude of an Indian group towards the Native as measured by the scale mentioned above, is compared with the attitude of a Cape Coloured group as measured by the same scale, we find that the average attitude of the Indian group has a scale value of 3.6 (P.E. ·100) while the average attitude of the Cape Coloured group has a scale value of 4·4 (P.E. ·078)—the critical ratio between these two scale values being 6·3.

The groups to whom the Racial Preferences Inventory was applied, were distributed as follows:

	Total.	M.	F.
Eng.-sp. S.A. (S.A. Parentage)	102	71	21
Eng.-sp. S.A. (English Parentage) ..	40	30	10
Afrikaans-speaking South Africans ..	80	76	4
Cape Coloured	47	35	12
Indians	20	20	—

The results for the different groups are set out in Table I.

* The lower preference value assigned to Natives by the Cape Coloured as compared with the Indian group, may, in part, be ascribed to the influence of the more unfavourable European attitude upon the Cape Coloured attitude as well as to the desire not to be lumped with "natives."

TABLE I.

Eng.-sp. S.A. (S.A. Parentage). N : 102.		(Eng. Parentage). N : 40.	Afrik.-sp. S.A. N : 80.	
Eng.-sp. S.A. ...	+2·10	+1·90	Afrik.-sp. S.A. ...	+2·40
Englishmen	+1·50	+1·80	Eng.-sp. S.A. ...	+1·35
Scotsmen	+1·15	+1·30	Hollanders	+ ·90
Afrik.-sp. S.A. ...	+ ·80	+ ·30	Englishmen	+ ·70
Hollanders	+ ·35	+ ·35	Germans	+ ·55
Germans	+ ·10	+ ·10	Scotsmen	+ ·40
Belgians	− ·10	− ·10	Belgians	− ·05
Jews	− ·65	− ·45	Portuguese	− ·50
Natives	− ·90	− ·80	Jews	− ·65
Portuguese	− ·90	− ·85	Natives	−1·20
Indians	−1·30	−1·20	Cape Coloured ...	−1·55
Cape Coloured ...	−2·10	−2·05	Indians	−1·75

Cape Coloured. N : 47.		Indians. N : 20.	
Cape Coloured	+1·95	Indians	+2·05
Englishmen	+1·30	Englishmen	+1·20
Eng.-sp. S.A.	+ ·65	Eng.-sp. S.A.	+ ·45
Scotsmen	+ ·35	Scotsmen	+ ·35
Hollanders	− ·10	Cape Coloured	+ ·10
Portuguese	− ·25	Portuguese	− ·05
Indians	− ·25	Natives	− ·10
Afrik.-sp. S.A.	− ·40	Germans	− ·15
Natives	− ·50	Belgians	− ·55
Jews	− ·60	Hollanders	− ·65
Belgians	− ·70	Jews	− ·90
Germans	−1·00	Afrik.-sp. S.A.	−1·00

A comparison between the two groups of English-speaking South Africans reveals two interesting points—one, that the group of Eng.-sp. S.A. (English parentage) reveals a higher preference for Englishmen than does the group of Eng.-sp. S.A. (S.A. parentage) as well as a much smaller difference in preference between Eng.-sp. S.A. and Englishmen; and two, that the preference of the group of Eng.-sp. S.A. (S.A. parentage) for Afrikaans-speaking South Africans is appreciably higher than in the case of Eng.-sp. S.A. (English parentage).

An examination of the scale values in Table I shows that the agreement in nationality or race preferences for the European groups is high while there are many discrepancies between the preferences of the European and of the Non-European groups. The inter-correlations of the scale values of all the groups is given in Table II.

TABLE II

		1	2	3	4	5
1	English-speaking S A (1)	—	—	—	—	—
2	English-speaking S A (2)	990	—	—	—	—
3	Afrikaans-speaking S A	839	758	—	—	—
4	Cape Coloured	054	088	− 083	—	—
5	Indians	000	071	− 362	380	—

Finally we may determine the degree of tolerance of each group by finding the standard deviations of the scale values since the greater the dispersion of the scale values, the greater the intolerance of the group The following are the S D values for each group

English-speaking S A (S A Parentage)	1 19
English-speaking S A (English Parentage)	1 15
Afrikaans-speaking S A	1 20
Cape Coloured	84
Indians	84

A NATIONAL LIBRARY SERVICE—LIBRARIES FOR BETTERMENT

BY

S B ASHER,
Johannesburg

Read 4 July, 1938

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 417-429, December, 1938.*

DISCOVERY OF THE FARTHEST PILLAR ERECTED BY BARTHOLOMEW DIAS

BY

ERIC AXELSON,

Formerly of Department of History, University of Witwatersrand, Johannesburg.

With 6 Text Figures.

Read 7 July, 1938.

1.—INTRODUCTORY.

It was customary for the Portuguese explorer of the 1470's and 1480's to carry with him up to half a dozen stone pillars or crosses. Neither the words "pillar" nor "cross" alone exactly describes one of these, for each comprised a pillar, seven feet in height, surmounted by a cross. It is accordingly preferable to retain the Portuguese word "padrão" (plural "padrões").

These "padrões" were erected partly as proof that the navigator had reached the neighbourhood he maintained; partly as proof of the priority of Portugal in the discovered waters; partly as symbol of Portuguese sovereignty in the discovered waters; and partly as a symbol of Christianity.

The locality of the last "padrão" erected by Bartholomew Dias in March, 1488, has for long concerned historians. It was usually held to have been erected on Cross Island in Algoa Bay (e.g. Theal, p. 205); or on the mainland behind Cross Island (e.g. Cory, in conversations with Prof. Fouché); or on Cape Padrone (e.g. Ravenstein "Geographical Journal" 1900, p. 6); or at the mouth of the Kowie (Schwartz: "J.S.A.A.A.S., 1912," p. 105). These opinions were, however, formulated without a full acquaintance of the historical sources at present known that shed light on the matter.

2.—HISTORICAL SOURCES FOR IDENTIFICATION OF SITE.

(a) *The Chroniclers.*

(i) Gois declared (I p. 71) that the island of the Cross, where Dias had placed his last "padrão" was five leagues to the west of the Bird Islands (the league at the time was variously estimated at from 17½ to 18 to the degree). Gois, however, in this was plagiarising, or using the same source, as Castanheda.

(ii) Castanheda made the same statement as Gois in almost the same words (I p. 13-14). He added in another chapter that

the "padrão" was on an island close to the land, 15 leagues to the west of the Infante River (I p. 6).

(iii) Barros wrote (p. 86) that the island was in lat. 33° 45′, and that it was called "of the Cross" because that was the name of the "padrão." Since there were two springs on the island it was also called the Penedo das Fontes. (The latitude Barros gave was only 1½′ out for Cape Padrone; 2½ for the actual site of the "padrão"; and 3′ for Cross Island. But of course readings at the time were correct to only ¼ or ⅓ of of a degree).

(iv) Correa, the earliest chronicler in point of time (he went out to India in 1512) has a fantastic description of the expedition of Dias (I p. 7-8) which has to be mainly rejected.

(b) *Contemporary (or nearly contemporary) Sources.*

(i) Duarte Pacheco Pereira: Pacheco Pereira accompanied Dias from Principe on Dias's homeward voyage. His "Esmeraldo de Situ Orbis," however, was not written until 1505 or thereabouts. He wrote (p. 148-9; Eng. trans. p. 160-1) that five leagues to the east of Algoa Bay was an island, little more than half a league from the shore, which was called the Penedo das Fontes, because Dias found there two sources of sweet water. The rock was also called the Island of the Cross. because Dias placed a "padrão" on the rock, which "padrão" could be seen when one was close to the island. The island was faced on the mainland by sand-dunes, whilst the land inland from the sand-dunes was low and green. The latitude of the island was 33° 45′. 25 leagues to the east was the Infante River. 8 or 10 leagues from the island were the Bird Islands. From the Bird Islands to the Infante River was 15 leagues.

(iii) The "Roteiro" of Vasco da Gama is the closest written source to the event. It is especially important since with da Gama sailed the pilot of Dias. The author of the "Roteiro" wrote (p. 15-6; Eng. trans. p. 14-5) that from the Island of the Cross to the Bird Islands was 5 leagues. From the Bird Islands to the last "padrão" was another 5 leagues; and from the "padrão" to the Infante River was 15 leagues.

(iv) João de Lisboa left an invaluable but extraordinarily neglected work. He voyaged almost incessantly as pilot between Portugal and India from the expedition of da Gama to his death in 1525. It is not certain when he wrote his "Llivro das Rotas de Lisboa ate a India e as Ylhas dos Açores . . . ," but his "Tratado da Agulha" was concluded in 1514. After describing the Cross Island group and the Bird Islands, he came to the Point of Carrascal (p. 154-6). From this point two hills were to be seen on a certain bearing. From the point a league to the east was an island that only looked like an island; for close inspection revealed it to be joined to the mainland. On the landward side of the island, and along the shore from it.

were sand-dunes. On the island, at the crest of a face of rock, was the "padrão." The island was five leagues to the east of the Bird Islands. 10 leagues beyond it was the Infante River.

(c) *Early Charts.*

A close examination was made of the Martellus, the Cantino, the Canerio, the Hamy, the Perestrêlo, B.M. Add. 21, 281 and B.M. Egerton 2803. These all still further proved that the "padrão" had been erected well to the east of Algoa Bay: to the east of Cape Padrone.

(d) *Conclusion from Examination of Sources.*

The previous results were tabulated as follows:

Gois and Castanheda	Castanheda	Barros	Pacheco	Pacheco	Author of "*Roterio*"	João
Infante River	Infante River 15 leagues	Infante River 25 leagues	Infante . River 25 leagues	Infante River 15 leagues	Infante River 15 leagues	Infante River 10 leagues
15 leagues Bird Islands 5 leagues Island of the Cross	"pādrão"	"padrão" and Penedo das Fontes and Island of the Cross	"padrão" 5 leagues C. Padrone 3 or 5 leagues Bird Islands	Bird Islands 3 or 5 leagues "padrão"	"padrão" 5 leagues Bird Islands 5 leagues Island of the Cross	"padrão" 5 leagues Bird Islands

It was impossible to argue back from the Infante River (nor is this the place for a discussion as to the identity of that river). But from the table and the charts it was obvious that the "padrão" was east of the Bird Islands; by probably five leagues, since this was the distance given by the two nearest and most reliable sources. It was patent that Pacheco had reversed his distances of the "padrão" and the Island of the Cross from the Infante, and in this been followed by Barros and most later writers; and that Gois, and Castanheda in one place had, possibly by mistranscription, reversed the direction of the "padrão" from the Bird Islands.

As soon as it had been decided that the "padrão" had been erected 5 leagues (i.e., 17 and a fraction nautical miles) east of the Bird Islands, it was a simple matter to find if the distance tallied with an island that was not an island: but a knoll of rock linked to the mainland with sand; 17 miles laid off on an Admiralty chart landed one squarely on a headland that was most significantly called False Island. The "Africa Pilot" confirmed that the appearance of the headland was such as to meet all the items specified by João de Lisboa, and most of Pacheco Pereira's.

Here it must be stated that, unknown to me, Captain Fontoura da Costa had already come to the same conclusion as to the identity of the site, and that he had published his opinion in "As Portas da India em 1484" in the "Anais do Club Militar Naval, 1935" (p. 34 of the off-print). I was unacquainted with this work until March of this year. But to Captain Fontoura da Costa is due all credit for being the first to settle on paper the question as to the site.

S. R. Welch, I found at the same time, had sought to identify False Island with the Penedo das Fontes (though for a false reason: the headland does not seem to divide the Bushman's and Bokness Rivers; "Europe's Discovery of South Africa" p. 208-9). But that the site of the "padrão" and the Penedo das Fontes were two different places is manifest from an examination of the Martellus and other early maps. Welch in fact placed the "padrão" on Cape Padrone (p. 208).

3.—First Visit to Site, December 26th, 1937.

A flying visit on the afternoon of this day satisfied me that False Island, or Kwaai Hoek, as it is locally known, really did satisfy all the conditions necessary for it to be the site of the "padrão."

False Island is midway between the Bushman's and the Bokness Rivers, in lat. 33° 44′ S. and long. 26° 38′ E. It is the name given to a series of three headlands. The easternmost headland, known as the First Kwaai, is 2½ miles to the west of the mouth of the Bushman's. West of the First Kwaai at a distance of a mile across a shallow bay is the Second; this projects rather farther into the sea than the First. About a third of a mile to the west of the second is the Third Kwaai. This projects the farthest into the sea, and is the boldest. To the west of the Third Kwaai the beach swings farther inshore, and then out again to the Cannon Rocks about five miles away. The headland of the Cannon Rocks is the Point of Carrascal of João de Lisboa, with Nanqua's Peak (known locally as Government Kop) as the more prominent of his two hills.

Each headland of Kwaai Hoek is faced on the seaward side with cliffs that rise to a total height of 90 feet. On the landward side, however, the ground slopes at a slighter angle, and finally merges into sand and sand-dune. This sand continues for all but a mile, to the edge of the coastal fringe of bush, which here occupies a dune-ridge running parallel to the coast, and rising to a height of about 200 feet.

It is obvious that from the sea an observer between N. 200° and 250° will clearly see the cliff-faced headlands; but if he is sufficiently far out he will see nothing of the linking strip of sand and sand-dune; nothing between the headlands and the bush-covered ridge. The illusion of an island will be complete. (See Fig. I).

Fig. I.—False Island. The third Kwaai Hoek seen from the landward side. On the crest can be seen the dump resulting from the main excavation.

A hurried search was made for the "padrão." It was assumed that this had been placed on the Third Kwaai, this being the most prominent, and the first to be seen by a vessel proceeding from Europe. But on none of the three was anything to be found.

4.—Second Visit to Site, January, 1938.

On my return to Pietermaritzburg, my brother, Mr. C. E. Axelson, M.Com., heard of the hostess of the quest, and promptly offered to drive me by car to the site, and join me in a more protracted examination of the locality. On January 15th camp was established in the fringe of bush immediately opposite the Third Kwaai Hoek.

A day's search of the three Kwaais failed to reveal anything of interest. But the discovery of sweet water one or two feet beneath the surface of the sand in two places between the bush and the sand proved how easily the place might be confused with the Penedo das Fontes.

Attention was concentrated on the Third Kwaai. The summit of the knoll was covered in low bush and scrub. Beneath this was sand. The sand was twenty feet in depth, extending to a layer of tufa that marked the limit of the cliffs. It was obvious that to maintain the "padrão" in an upright position in this sand a base of boulders would be necessary, carried without doubt from the base of the cliff. In case these

boulders and the "padrão" might have become covered in sand, pointed steel rods were driven into the ground in systematic exploration. Work was started on the highest ridge of the knoll, whence the ground drops a sharp 20 feet to the edge of the 70 foot cliff. The commencing point was a surveyor's beacon, which occupies a central position on the ridge (though the ground 35 feet east of the beacon is to-day 18 inches higher). The rods were inserted every three feet in a line due east of the beacon (in the direction of the rather prevailing wind). The seventh probing revealed something solid three feet beneath the surface. Further exploration revealed obstructions between one and four feet beneath the surface, with a diameter of about ten feet.

A hole was hurriedly sunk. Boulders were found, of local limestone and dune-rock, of such a size that the largest could be carrreid with facility by two men. Later, a piece of limestone was removed from the hole that could nowhere in the vicinity be matched. It was much denser, much more crystalline, much more attractive in appearance than the local rock, that was either soft and white and chalky in nature, or composed of pebbles set in a calcareous matrix. This piece had moreover two level and almost parallel edges, 8½ inches apart. These faces might have been the result of natural jointing; but their appearance was more suggestive of artificial handwork. Further smaller but similar pieces were excavated.

It seemed reasonable to suppose that these were fragments of the "padrão," shattered by some unknown means. Probably lightning was the villain of the piece. Interloping Frenchmen may just conceivably have been responsible. Once shattered, the work was probably carried further by aborigines.

The possibility suggested itself of a descent of the other and larger fragments over the cliff. At the next low tide (it was fortunately the time of full moon) the rocks were searched at the foot of the cliff. My brother discerned in a pool a face that was rectangular in shape, with the upper part of another face barely visible at right angles to the first. The faces apparently belonged to a block of stone, heavily covered in weeds and other marine growths. A hurried chip revealed the block to be composed of the same kind of peculiar limestone as that of the pieces found on top of the cliff. (See Fig. II).

The following day the block was wedged loose from the sides of the trough that had been worn for it in the softed surrounding dune rock. The block was lifted, bound with rope to timbers, and conveyed beyond the reach of the incoming tide. It was found to be 29½ inches long, by an average of 8¼ and 8¼. The next day the block was conveyed by donkey-sledge across the waste of sand, eventually to make its way, with the other pieces, to Alexandria and Pietermaritzburg.

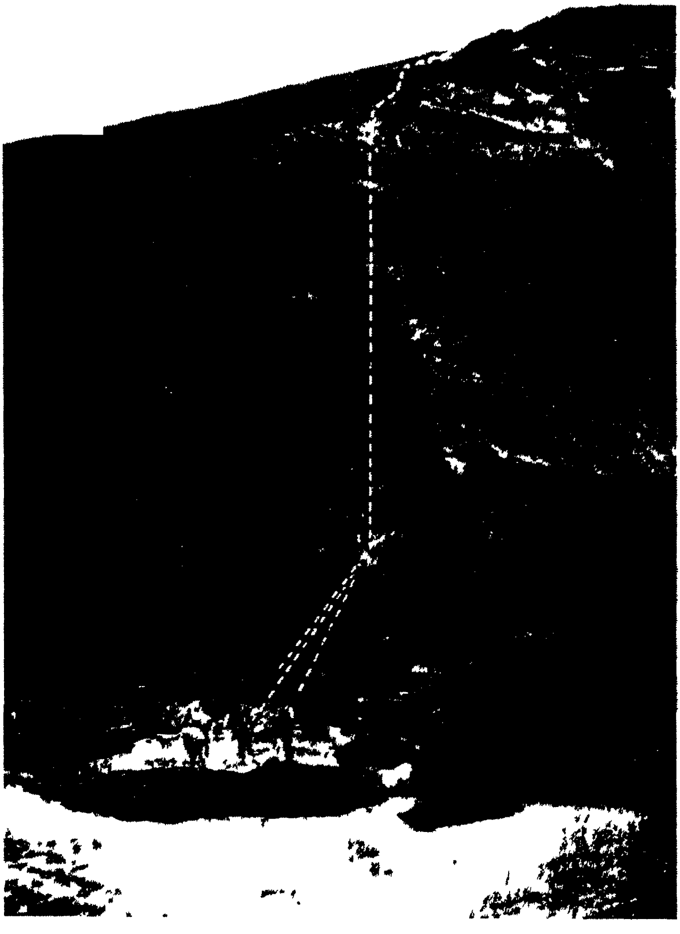

Fig. II.—The seaward face of the third Kwaai, showing the probable route of descent of the bulk of " padrao."

5.—Third Visit to Site, February-April, 1938.

The University of the Witwatersrand immediately interested itself in the matter (it had already supported me for two years of research in Europe). Professor Fouché went to the vast trouble of a special visit to Pietermaritzburg for the purpose of examining the finds. Such doubts as I might still have had as to authenticity were quelled when Professor Fouché rose from

his examination of the block, and exclaimed, "I have been on my knees before the true cross." Dr. L. C. King confirmed that the block could not be of natural occurrence, but had been chiselled or sawn to its rectangular shape.

Absolute certainty, however, could only be secured by the discovery of further pieces; pieces especially bearing the inscription that was known to have been carved on the "padrão." The University accordingly financed me to undertake a thorough excavation and examination of the site. I arrived at False Island on the 18th February. Tent was pitched on a platform cut in the side of a dune just above high water mark between the Second and Third Kwaai Hoeks — the only comparatively sheltered spot. Six weeks were spent at Kwaai Hoek. The assistance of local coloured labour was invoked, and gradually the number of boys employed rose from one to five. Work was divided between the top of the cliff and the rocks at its base.

i. *Crest of Cliff.*

The crest was systematically explored by steel rods for further hidden rocks. But nothing was found outside the area already mapped.

A base line was set out, running N. 80° and 260° through the beacon. The line was in line with the most prominent hill (on the western horizon): Nanqua's Peak. The line ran approximately along the highest ridge. A grid was laid out in five foot squares. By this system, which enabled me to attach three co-ordinates to every fragment recovered, each specimen can be returned with precision to the spot from which it was taken. Excavation started round the crucial spot in foot layers. All material excavated was screened (through ¼in. screening) and sieved.

Fragments at once came to be found of the typical limestone of which the "padrão" was constituted. Most were very minute, being but a fraction of an inch across. The largest pieces measured up to 8¼ inches across—the width of the pillar. In all 5,000 odd pieces were excavated.

The remains were removed to the University of the Witwatersrand. There a sand-bath was constructed, in which endeavours were made to fit together as much as possible of the fragments. The portions recovered from under the water were cleaned as much as possible from their incrustations of algal limestone, serpula, balanus, ostrea, lamellibrachs and gastropods (identified by Professor T. W. Gevers). It was found possible to aggregate a total length of six feet six inches. Much, however, was missing—probably 25 to 35 per cent. of the weight. There was for instance no trace of the block that was often to be found, bearing the coat of arms, between the pillar proper and the cross. In places the width of 8 odd inches was reduced to a bare 3½ or 4.

An important discovery, however, due almost entirely to the efforts of Professor van Riet Lowe and Professor Fouché, was that the eight largest pieces carrying lettering fitted into and against each other. The bulk was revealed of four lines of writing, with four or five letters in each line. (See Fig. 3). But the lettering was so worn as to be illegible. (See Fig. 3). On a side at right angles to the main lettering was the bulk of another word, which I read as *Portu(gal)*.

Fig. III.—Fragments of "padrao" showing lettering.

6.—Conclusion.

(a) It remains to thank those responsible for the success of the research. First would I mention the University of the Witwatersrand (and especially Mr. Raikes, Professor Fouché and Mr. Thomas), but for whom the excavation would have been impossible. Secondly, I thank my brother, who made

possible the second visit to the site, and the discovery of the largest piece of the pillar that was recovered. Finally, I thank the many people who rendered assistance during the third and final stay; especially would I mention Mr. R. N. Arbuthnot, the magistrate of Alexandria, and Mrs. Arbuthnot; Professor Mountain, and Mr. Fred Holland and Mr. W. Lane.

(b) The authenticity of the fragments appears to be guaranteed by the coincidence of the following factors:

(i) The site was identified from historical sources by two independent researchers.

(ii) At this site were found definitely man-worked inscribed fragments on non-local rock.

(iii) This limestone has been stated by the Director of the Geological Survey to be unknown in South Africa. But there is nothing to prevent it from being of Portuguese origin. Superficially it certainly greatly resembles the limestone deposits north of the Tagus. (The Historical Monuments' Commission could, if it desired, compare the fragments with the fragment of the Luderitz Bay "padrão" in the South African Museum; or introduce samples of limestones from Portugal).

(iv) The appearance of the fragments is compatible with expectation. What was probably the worked end of an arm of the cross proper was found, whilst the width of the pillar, down even to the taper, compares exactly with that of the Luderitz Bay "padrão."

(v) The inscription is highly similar in appearance to known contemporary "padrão" inscriptions.

It accordingly seems impossible to resist the conclusion that these are indeed fragments of the Union's oldest historical monument.

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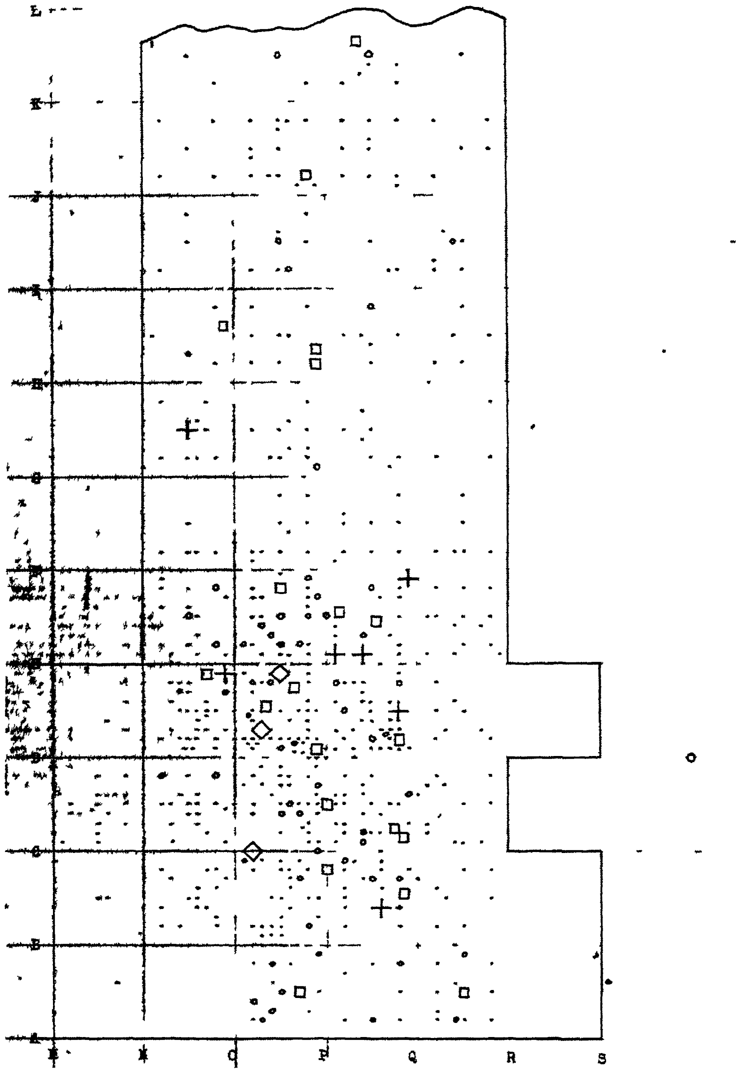
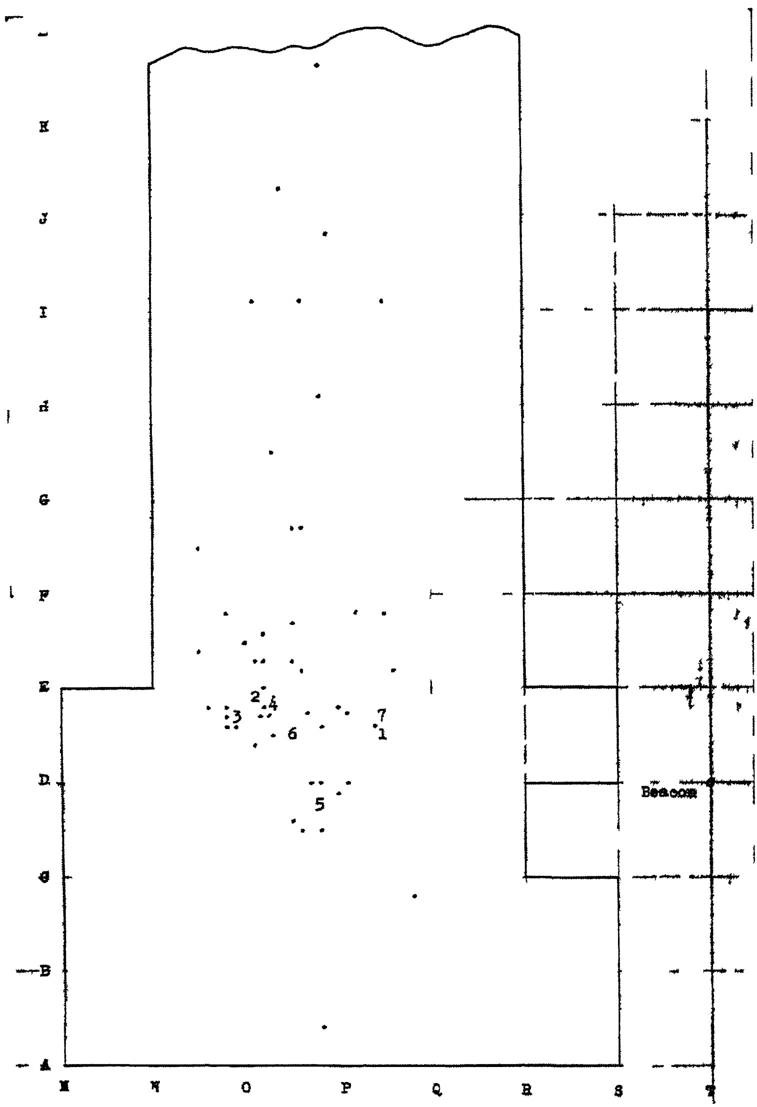
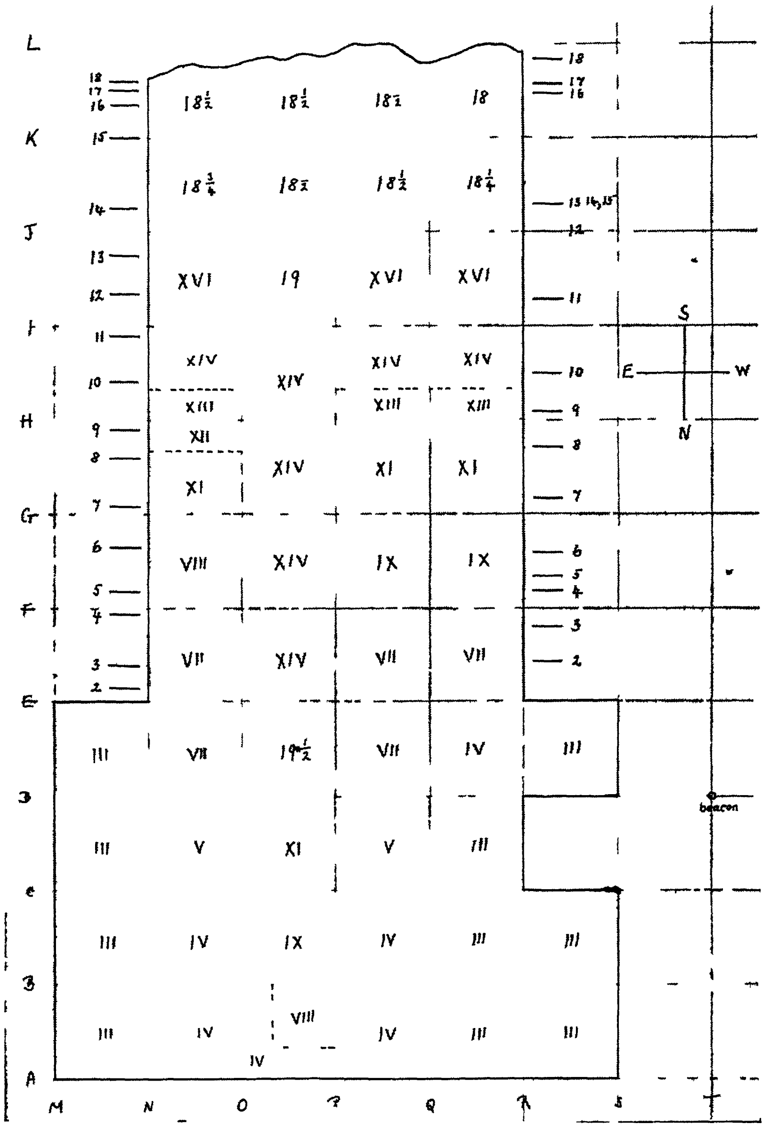


● = fragments of "padrao" aggregating approx vol. of cube, edge 1in.
○ = „ „ „ „ „ 1-2in.
□ = „ „ „ „ „ 2-4in.
+ = „ „ „ „ „ 4-6in.
✧ = „ „ „ „ „ 6in.



Dots represent approximate positions of centres of boulders of local rock

1 =	position of a small piece of iron	(depth of 3 feet)
2 =	position of a piece of lead, $4\frac{1}{2}$ inches long	(depth of 2 feet)
3 =	position of a piece of lead $1\frac{1}{2}$ inches long	(depth of 2 feet)
4 =	position of a piece of lead 1 inch long	(depth of 3 feet)
5 =	position of a small piece of iron (?)	(depth of 3 feet)
6 =	position of pieces of wood-ash or charcoal	(depth of 8 feet)
7 =	position of a small piece of glass	(depth of 3 feet)



Figures represent depth of each square, in feet, from base of beacon
Arabic figures denote clearance to rock bottom.
Side figures show contour depths in feet from base of beacon

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXV, pp. 430-431, December, 1938.*

THE A.C.H. INDEX AS APPLIED TO BOYS AND GIRLS IN CERTAIN PRETORIA SCHOOLS: AGE AND SEX INCIDENCE OF MALNUTRITION IN 1,275 CASES

BY

HARDING LE RICHE,

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Read 8 July, 1938.

SUMMARY.

In a nutrition survey conducted on European children in Pretoria schools, it was decided to use the A.C.H. Index of Nutrition (Franzen and Palmer, 1934) on those aet. 8 to 12 years incl. Technique used was slightly different from workers mentioned, in that all measurements were taken on the skin (boys), over one layer of thin clothing (girls); for chest depth, sum of extreme expiration and extreme inspiration taken at xiphoid level as described by McCloy (1936).

The children were from all economic groups: 658 girls, 617 boys.

The following table summarises the sex and age distribution of the children "selected" by the index:—

Age in Years	MALES			FEMALES		
	Observed Incidence of Malnutrition in total number	S.E.	Chance Fluctuation (±2 S.E.)	Observed Incidence of Malnutrition in total number	S.E.	Chance Fluctuation (±2 S.E.)
	%	%	%	%	%	%
8	10·3	2·8	4·7—15·9	4·5	2·0	·5— 8·5
9	9·4	2·7	4 —14·8	7·0	2·2	2·6—11·4
10	17·8	3·4	11 —24·6	6·9	2·1	2·7—11·1
11	24·5	4·1	16·3—32·7	8·6	2·5	3·6—13·6
12	27·8	3·7	20·4—35·2	13·0	2·8	7·5—18·6
Total	18·3	1·5	15·3—21·3	8·2	1·1	6·0—10·4

Findings.

1. Comparing boys and girls, there is significantly more malnutrition among the boys.

2. In both groups there is a tendency for malnutrition to increase with age. This phenomenon is more marked in the case of the boys.

3. It would appear that there is a greater deficiency of soft tissues (subcutaneous and muscular), for skeletal structure, among the boys.

Discussion.

1. Basal metabolism of boys is higher than that of girls (du Bois, 1936). Would appear that boys do not receive sufficient food in view of (a) their increased metabolism (b) their greater activity.

2. Boys might be more fatigued on account of greater activity, leading to defective ingestion and absorption of nutrients.

3. Female organism probably more resistant to unfavourable milieu, as propagation of species is more closely dependant on her than on the male. Greater resistance of female to unfavourable conditions apparently present from moment of conception, as differential mortality operating against male sex apparent already in intra-uterine life (Winston, 1932).

4. The necessity for good feeding and absence of fatigue is emphasized, especially with reference to physical training.

5. The need for research into the question of nutrition, growth and normal physiology of S. African children—of all races—is stressed.

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South African Journal of Science, *Vol. XXXV, pp. 432-450, December, 1938.*

EVENING DISCOURSE.

EARLY MAN AND PAST CLIMATES IN SOUTH AFRICA

BY

C. van Riet Lowe,

Director, Bureau of Archæology, Department of the Interior.
Professor of Archæology, University of the Witwatersrand.

Read 4 July, 1938.

1. Introduction.

By way of introduction to our talk this evening, I wish to do three things: First, I want to explain that I had nothing to do with the choice of the title. This was done for me, and when the wish was expressed that I should adhere to it, I did so—somewhat reluctantly, I must confess. My reluctance was due to two things: In the first place I was anxious to talk to you about the care of ancient monuments—a subject that is, I am sure, very dear to all of us. But my suggestion was not favourably received. I can only imagine that this was in part due to the fact that the title suggested a discourse on the uses of cement and seccotine rather than on an explanation of the manner in which the ancient homes (both historic and prehistoric) and works of man and nature are preserved and cared for by the State. The Commission for the Preservation of Natural and Historical Monuments, Relics and Antiques is doing sterling work in our country, and I felt you would wish to know something about it. Our Association has also done, and will. I hope, continue to do, much to support this work, and I welcomed the opportunity of such a platform as this—but it was not to be.

In the second place I was a little reluctant to talk about early man and past climates in South Africa because the last popular evening lecture that was given in Natal also dealt with "Climate and Man in Africa." It was delivered by General Smuts in Durban in 1932, and he dealt with his subject in a manner that I cannot hope to emulate (1). So much has, however, been added to our knowledge of early man and past climates on this continent during the past six years that a review of the problem is eminently worth while at this stage. That is my only justification for following so closely in the tracks of our great leader.

The third thing I wish to do is just briefly to describe to you certain changes that have taken place in the landscape of

Africa since man's appearance on this great and important stage. The life of an individual is so short and so circumscribed that between his infancy and his old age he sees little or no change in the countryside with which he is familiar. The hills remain the same; so do the valleys; new buildings may have been erected here and there, and erosion may have effected certain superficial changes in the landscape, where the ground was poorly covered by vegetation, but on the whole, the countryside in which he grew up has much the same contours and looks much the same. The *ethos* of the place may have changed, but its material background, its essential setting, seldom seems to have undergone any change. And so, earthbound as we are, and limited as the experience of most of us of necessity is, we are lulled into a feeling of security and seldom give a thought to the changes that are constantly taking place around us. Only those of us who have experienced earthquakes, or have witnessed the disruptive and terrifying effects of a volcanic eruption can know how instable this earthly setting can be. Geologists and astronomers are wiser men and appreciate the instabilities of our surroundings more than most of us, but few of us are astronomers or geologists, and if the object of the " Evening Discourse " is what I have been given to understand it is, namely, a popular address designed to interest the non-specialist, then I must assume that the majority of us here this evening are non-specialists. This being so, I would like, in this introduction, to describe to you certain changes that have taken place in the landscape around us since our prehistoric forerunners first appeared on the scene. To do so, I wish to take you on a journey from Nairobi to Kisumu, across Victoria Nyanza to Entebbe, and thence to Ruchuru, just across the eastern boundary of the Belgian Congo. As the crow flies this is a journey of about five hundred miles—as far as from Pietermaritzburg to Plettenberg Bay—a comfortable two-day run by car, or an easy morning's flight.

From Nairobi the road to the west climbs slowly but steadily over undulating land towards the serrated crest of the Ngong Hills. From woodland, coffee plantations and fields of pyrethrum, it passes into lovely open park-like country. Then with a sharp turn to the right one finds oneself in a saddle in the ridge—and suddenly and most surprisingly in another world! We are at the top of a steep, almost precipitous scarp, descending in a few abrupt steps to a plain over fifteen hundred feet below. The country is cut through as by a knife. The hills on which we stand are only half a range: they rise gently from the east, but have no western half, because they happen to have been cut right through. About forty miles to the west the plain below is bordered by another scarp—the mirror, as it were, of that on which we stand. Like a great wall, we see it faintly through the mist, while below and in front of us, in the middle of this broad ribbon of plain is an extinct volcano. North of it lies another—Longonot—beyond which we

get a glimpse of Lake Naivasha—and other volcanoes rise in the south, and beyond them we see the glistening shores of Lake Magadi. We are looking down into the Great Rift Valley From the crest on which we stand we shall descend and motor for nearly one hundred miles before we emerge at Mau Summit on the far side Our road will pass numbers of extinct volcanoes and several beautiful lakes—all nestling peacefully in the floor of the Great Rift Valley

Continuing westward from the Mau range, the road drops again through undulating and broken land until we reach Kisumu that nestles peacefully in the Kavirondo Gulf of Victoria Nyanza. Nearly two hundred miles across the waters of this great lake lies Entebbe—the Pearl of Uganda—in an exquisite setting From here we continue westward along a road which gradually climbs through papyrus swamps and beautifully wooded country until we reach the Kanaba Gap that overlooks the Belgian port of Ruchuru, some fifteen hundred feet below. The scene from the Kanaba Gap is essentially the same as that which surprised us from the Ngong Hills To describe this, I shall turn to Huxley: " You stand on a scarp; below you is a plain extending north and south; beyond the plain rises another scarp, a formidable wall of mountains Nor are the volcanoes and likes wanting. To the north shimmers Lake Edward; to the south rises one of the most extraordinary chains of volcanoes in the world, eight of them, ranging from ten to nearly fifteen thousand feet in height, right across the valley in a single transverse row.

" Here again there are two kinds of country—the uplands extending east and west for hundreds of miles, and the trough that is cut through them from north to south. . . . It is in the trough, steep-sided and flat-bottomed, that the lakes lie and the volcanoes rise.

" The impression on the eye is remarkable enough; but when knowledge and imagination are called in to aid, the effect is overwhelming" (2).

Thanks to the labours of Leakey (3), Solomon, Nilsson (4), and others, our knowledge to-day is such that we are able to say quite definitely that the great eastern rift—the so-called Great Rift Valley—came into existence only *after* man as a maker of comparatively advanced stone implements had long been in occupation of this continent. Before the vast earth movements that gave rise to this great crack in the earth took place, the area presented a very different appearance from that which it does to-day. Vast rolling plains stretched for hundreds of miles, and on these Man, the essential hunter, moved and had his being. In his tracks he left countless numbers of stone implements, which are now being recovered from deposits laid down in old swamps—deposits that were cut through when the rifting started, so that portions are now found

on the Kinangop Plateau above the valley, and portions on the lower ledges and in the depths of the Malewa Gorge below.* This rifting cut, as it were, into the bowels of the earth. Lava was spewed up and volcanoes rose and spread their ashes and ejectementa over a vast area—and buried beast and man alike. But the tools of man were of stone and these, fortunately, have been preserved for us. To recover them from under great sheets of volcanic material that has turned to rock in the millennia that have elapsed since these cataclysmic disturbances took place is a most impressive experience. Yet generations have come and gone in this great valley, and have seen no change. The lakes, pink-bordered by great flocks of flamingoes, the hills, the streams, the bird and animal life are to the son what they were to the father—and peace and stability reign.

When the history of man has been more elaborately worked out we shall, I venture to suggest, look upon this period of rifting, or at least upon that portion of it that gave rise to the eastern or Great Rift Valley, in which Naivasha and Nakuru lie, as the the greatest tragedy in the history of man. Yet this is only one of the major events that reveal changes that have taken place since man's appearance on the earth.

We have not anything quite so spectacular or impressive in other parts of Africa—though if one may judge from appearances from the air, I suspect something similar between the northern shores of Lake Nyasa and Lake Rukwa—but we do know that our greater rivers, the Nile, the Zambesi, and the Limpopo for example, and lesser streams such as the Vaal, the Eerste, the Great Fish, the Umfolosi, and the Tugela at our door have altered their courses and deepened their channels appreciably, in instances very considerably, since man first appeared on the South African stage. The Victoria Falls, for example, were not in existence when makers of the great hand-axe culture first appeared in this Valley. There certainly was a great waterfall at that remote time, but it was not where it is to-day. Five gorges have been cut, and by backward erosion the actual precipice over which the water falls has been

* When I first saw stone implements in situ in Kamasian swamp deposits, where these occur on steps of the Kinangop escarpment, I was not convinced that the implements became imbedded during Kamasian times. It occurred to me that they may have sunk into the Kamasian beds while these were exposed during the Gamblian wet phase. I expressed my difficulties to Dr. Eric Nilsson, who confirmed Leakey's views by stating that it was his impression that the tools must have sunk into the sediment when this was part of the bottom of the Kamasia lake. He added that he had seen no disturbances in the layers above the tools, which must have been the case had they been deposited at a later date, and that after the dislocations which brought the Kamasia sediment to different heights in the Kinangop escarpment, there could not have been any possibility of the tools sinking into the sediment as this must have dried up and hardened rather quickly. The view of so eminent an authority on the great African rift system corroborates that of Leakey and others, and is therefore most valuable.

moved upstream for at least five miles. In other words, four great waterfalls—each at least as great as the present—have come and gone since man first appeared in this Valley. There is reason to believe that since the first human set foot here at least " two arid and two pluvial periods have supervened, and that during the former the Zambesi must have shrunk to a mere stream, or entirely dried up, and a bed of blown sand was deposited across the valley. With the increased humidity during the pluvials the river resumed its activity, removed the accumulated sand and continued the erosion of the Gorge " (5). The investigations carried out at the Falls covered a very small area, but the picture that has been reconstructed is an exceedingly valuable and illuminating one (6). Further south we have been fortunate in being able to carry out geological and archæological investigations over a very much wider area and in a very much richer field. I refer to the recently completed joint geological and archæological survey of the Vaal River Basin (7). This survey has revealed a long and fascinating story of climatic oscillations and human activities during the Quaternary Age in the hinterland of the Union. I propose, therefore, to start the more serious portion of our talk this evening by reviewing the activities of man and climatic changes as they are now known to us in this region.

2. Climatic Changes and Human Industries during the Pleistocene.

The sequence of climatic changes is revealed in successive deposits of coarse and fine gravels and grits, as well as by deposits of fine silts and sands—some laid down by water, some by wind. Very wet phases are characterised by long periods of continuous erosion, less wet by aggradations of coarse gravels and grits when the erosive action of the water was insufficiently strong to carry away the coarse material yet sufficiently intense to carry off all the fine matter borne in suspension. Semi-arid phases are characterised by the formation of calcareous tufas or calcified sands, and by deposits of laterite—our common *ou-klip*—while arid or dry periods are typified by accumulation of wind-borne sand as well as by wind erosion. As background to these we have fossils in the deposits and also stone implements.

The archæologist's great anxiety is that the sequence of events should be established on purely geological grounds, but that, unfortunately, is not always possible. Prehistoric archæology is really a specialised branch of geology; the two subjects are inseparable. Where our strata do not overlie each other in direct superposition we may be forced to use included implements as zoning fossils in order to piece the evidence together. When we add the palæontological evidence to the archæological we have all we need to fill any gaps that may exist in the stratigraphical record. In a regional survey this procedure

is orthodox and straightforward, and leaves nothing to be desired where we have a sufficient number of widely scattered sites to check and re-check results and conclusions. This, happily, was the case in the Vaal River Survey. We were able to check and re-check our conclusions, and thus completed our work with a modicum of satisfaction.

Where we have no spectacular terraces, deposits of coarse and fine aggregates or beds of sands and silts that betray the climate of the times when these terraces were cut or these deposits laid down, we turn to a study of the adaptation of animals and plants. This often enables us, not only to obtain some information about the mechanism of evolution, but also to reconstruct the biotope of the time those deposits were laid down. As the biotope largely depends on climatic conditions, it is possible occasionally to draw conclusions which add considerably to our knowledge of past climates. Very little work has been done in South Africa in this direction, but an ever-increasing amount is being done in Europe, where the introduction of biological modes of thinking into palæontology has, undoubtedly, increased the significance of palæontology not only for geology, but also for prehistoric archæology.

The story we are to consider this evening starts at the beginning of the Quaternary Age, and in actual time takes us back for the best part of a million years. This is not uncertain guess-work, as is so often the case when estimates of geological time are made—for the brilliant work of the Soviet astronomer Milankovitch (8), and the German palæontologist, Zeuner (9), enables us to refer to absolute time in the Quaternary with comparative accuracy. Thanks to the work of such men as these the essential canvas on which all pictures must be reconstructed is slowly assuming shape. To appreciate the evolution of man adequately we must, as I indicated in my paper on regional surveys to this Association a few days ago (10), know as much as we can about his environment and associates, and when we have some idea of absolute time and not merely relative, as is so often the case, our appreciation is intensified. But here I must issue a word of warning: a consideration of time brings us face to face with difficulties, not the least of which, in such a popular talk as this, depend on the use of scientific terms. The leading article in last Saturday's "Natal Witness" told us that "one of the essential aims of the organisers (of this Congress) is to introduce to the public some of the problems of science, and to bring before the layman the views of the scientist on matters affecting human society"—but it, unfortunately, did not tell us how the scientist on whom this duty falls can do so without using scientific terms. One of the great difficulties the scientist experiences whenever he is called upon to deliver a popular lecture brings in the use of these terms. Many have voiced the opinion that it is indeed regrettable that the man of science cannot escape the jargon of science. I am,

however, convinced that so far as the subject of early man is concerned, the growth of general knowledge during the past few decades has been such that the so-called man-in-the-street is familiar with most, if not all, of the terms we shall use this evening.

Less than a generation ago the very word "archæology" conveyed little or nothing to the average individual, but such is man's interest in himself—his past, his present, and his future—that it is no uncommon thing nowadays to hear even children use such terms as pleistocene, palæolithic, and so on, This is due to the fact that the great value of familiarising ourselves, not only with the written record, but also with the unwritten, has so impressed itself upon us that any news that deals with man—whether of the historic or the prehistoric period—is literally front-page news in the daily Press. One cannot give the Press too much, especially in a country that is a rich store-house of the past as is that in which we live. This is a great consolation to me, for in the course of this evening's talk I shall not be able to avoid the use of terms that were branded as dreadful scientific jargon less than a generation ago. When the terms I may use are not generally understood, we must blame those who chose the subject of our talk, and not the subject!

When we go back a million years, we reach the dividing line between the Pliocene and the Pleistocene, and here we are immediately up against another, and this time a very real, scientific difficulty. The terms Pliocene and Pleistocene are essentially European, and the dividing line between them is clear only in certain very limited areas in Europe. As Söhnge and Visser recently pointed out, these chronological terms "were first used to denote the ages of certain marine beds containing fossils, the differentiation being based on the percentage of extinct species present. When applied to continental deposits even near the type areas, such a classification requires modification, and in South Africa it leads us into difficulties when marine beds alone are considered. For example, on the basis of percentage of extinct species, a raised beach at a certain level on the West Coast would be called Pliocene, while one at the same level on the South Coast, or in Natal, would be Pleistocene. Since, further, it is not possible as yet to correlate our post-Cretaceous (i.e. post-Pliocene) continental deposits with marine beds, it becomes apparent that a division between Pliocene and Pleistocene must be based on grounds other than those originally used" (7).

Hopwood, following Haug, suggested that the separation between the two periods be made according to the presence or absence of true elephants, true horses and true oxen—adding that the presence of any one of the genera *Elephas*, *Equus* and *Bos* (including *Bison*) should be sufficient reason for assigning a Pleistocene Age to the deposit in which it is found. The

suggestion is an attractive one and seems gradually to be gaining ground. Provided the necessary fossils are present and that the generic terms are interpreted in a wide sense, I personally feel we cannot, at this stage, hope to improve this definition. The problem of correlation is of vital importance to the archæologist, for until deposits that contain human remains can be correlated in time we are not in a position to say whether any particular culture that is widely diffused in space was practised first in this part of the world or in that—in other words, we cannot hope to trace the centre and avenues of diffusion of any particular culture.

If we accept Hopwood's definition of the Pleistocene, then the oldest deposits that contain stone implements in the Union must be regarded as early Middle Pleistocene, and from this time onwards we have an uninterrupted story of the evolution of human arts and crafts right up to the present.

The Lower Pleistocene is characterised by a prolonged pluvial period when such rivers as the Vaal deepened their channels by several hundred feet, and where the main stream moved laterally for as much as twenty miles. The long slopes down which the channel slowly eroded its way are terraced, and on these terraces we find aggradations of gravels—known as the *Older Gravels*—and silts which show that this pluvial period varied in intensity from time to time. Yet nowhere so far as we know do these deposits contain remains of any human industry that was practised at that time. They have, however, yielded remains of a true but extinct elephant (11) and must, while we adhere to our definition, be regarded as Pleistocene.

Man first appeared on the scene towards the end of this long early Pleistocene pluviation. His tools belong to a simple Pebble Culture—just small, rounded river pebbles simply and crudely flaked into chopping, scraping and pointed or digging implements. They are found on the Older Gravels that were deposited at that time, and wherever they occur in later deposits, they are abraded and rolled to such an extent that it is obvious they were derived from an earlier horizon.

But the rains did not last. A long dry period that may have been accompanied by earth movements followed. The only trace of man centres on rare occurrences of simple pebble tools he left in his tracks. In the course of time, however, the rains increased to give rise to what has been termed the First Wet Phase, when the country once again enjoyed a much higher rainfall than it does to-day. The vegetation must also have been much richer and game more plentiful. This Wet Phase lasted over very many millennia, and although the rainfall remained high it was not consistently high. Actually, three peak rainfall periods have been recorded, with two intervening less wet periods. The curve of rainfall may be visualised as somewhat like that of simple harmonic motion, the fluctuations of which are revealed

in shelves cut by rivers and in terraced deposits of coarse and fine aggregates on these shelves. The coarse aggregates of this phase are known as the *Younger Gravels*. It is from such deposits that we are to-day recovering the stone implements man left in his wanderings during this period. We are also recovering the mineralised remains of animals that roamed the countryside with him. All these are extinct—elephants, hippopotamus, giraffe, antelope, carnivores, horse and buffalo—an impressive series that still awaits description.

That man occupied South Africa during the first peak rainfall period of the First Wet Phase is proved by the occurrence of worn and unworn stone implements included in the aggradations laid down during this phase. The implements belong to the African Abbevillian Culture—a culture that heralds the dawn of the Stellenbosch Culture of our Earlier Stone Age. From the beginning of this First Wet Phase to its end we have traced the evolution of human industry through at least five successive stages of the great hand-axe culture—variously represented by the African Abbevillian and Acheulean or Stellenbosch Cultures—when hand-axes, cleavers and crude cutting and scraper-like tools were made. Each successive stage is included in a deposit that is stratigraphically later than its predecessor. The gradual refinement of end-products, craftmanship and technical processes is beautifully revealed, and nothing except the man who made these tools is left to the imagination. We are in complete ignorance of the type of human who was responsible for this great hand-axe culture. When General Smuts addressed this Association in Durban six years ago, it was thought that *Homo sapiens* was the maker of hand-axes, cleavers and crude scrapers that combine to form this culture, but subsequent investigation has shown that the evidence submitted in support of this is inacceptable, and we have therefore had to make a fresh start. Smuts was misled as we were all misled.

All we know with certainty is that the folk who practised the hand-axe culture roamed all over Africa from north to south and from east to west. Tools of this period are found in great abundance in the basins of the Nile, the Congo, the Zambesi, the Limpopo, and all over the Union. His industry spread as far afield as Great Britain in the north, and India in the east. Africa appears to be the home of this culture. It would seem that from here it spread north into Western Europe—Spain, France and England—and eastwards through Palestine into India, and probably even beyond. Tools of this period have not been found in Eastern Europe or in the Far East, but they occur in countless numbers in the other areas referred to. So alike are they generally, and so alike are the processes by which they were made, that it is impossible to escape the conclusion that they reached these continental extremes by a process of diffusion from some common centre. Yet as soon as

we attempt to correlate the time horizons when obviously related cultures appeared in these extremes, we find ourselves up against an almost blank wall. I say "almost blank" because I do not believe the problem is insoluble. Considered by themselves, our zoning fossils, whether these be the output of human industry or the mineralised remains of animals, may be misleading and an inadequate index to relative age, but the climatic oscillations were too great and widespread not to be a most significant factor in any attempt at correlation. We shall discuss the possibility of climatic correlations later. Let us just note in passing that the progressive humans whose industry evolved so markedly during this First Wet Phase occupied the whole of the Union before the Victoria Falls (as we know them to-day) existed, and before the vast earth movements that gave rise to the Great Rift Valley were complete.

Remains of stone implements of those far-off days are also found in deposits laid down by rivers that now flow in remote and often considerably deepened channels. In one case we find these implements deep-buried in gravels that were deposited by the Vaal when it flowed over fifteen miles away from its present course. But the halcyon days of the First Wet Phase did not last. After the third peak rainfall period the rains continued to diminish and a long comparatively dry period set in. These periods—the first wet and the first comparatively dry—must not be measured in centuries, or even in millennia, but in tens of thousands of years. The story of early man and changing climates in South Africa is an exceedingly long one. To appreciate it we must accustom ourselves to think in figures that we optimistically attach to the charities of millionaires!

The lessening of the rains and the long-continued semi-aridity that followed gave rise to a comparatively inhospitable period, which the primitive hunter survived only while he remained near permanent water. That is why tools of this period are seldom found far from streams or fountains. Nevertheless, the survival of our prehistoric forerunners through this period is proved by the occurrence of his implements in deposits—mainly calcified sands and calcareous tufas—that were laid down at this time. But at last the long drought broke, the rains again increased and ultimately gave rise to the Second Wet Phase, which, in accordance with our definition, must be placed in the Upper Pleistocene. Plant life revived, animals increased in numbers, and in their wake, Man, the hunter, reappeared in increased numbers. His industry still centred round the great hand-axe culture, but the tools he made are now generally much more refined than those of the First Wet Phase. The hand-axe is now accompanied by several new types that reveal a great advance in technical skill. The cleaver is still present, but it, too, is more refined and generally smaller. In addition we have a variety of scraping, cutting

and chisel-like implements and points that may have been hafted. This Second Wet Phase lasted for a very considerable time. In certain areas it swept away deposits laid down during the First Wet Phase; in others it gave rise to aggradations of coarse, sub-angular gravels (known as the *Youngest Gravels*) and grits that have survived only in the tributaries of our main rivers. The culture of this period is known as the Fauresmith, because it was at Fauresmith, in the Orange Free State, that tools that characterise this horizon were first discovered. It was, if Broom is right, the age during which the Sterkfontein Ape roamed the Witwatersrand (12). This is a very important point, and one about which I must say a word. I am no comparative anatomist or physical anthropologist, and am able to trace the movements and activities of prehistoric man only by the tools he left in his tracks, but it must be obvious to us all that the terms which we attached to the ages of the geological deposits that yield remains of man's industry and the creatures that lived at the time must be meticulously chosen and defined. If I may add to the words of Stibbe (13), I would say: "It is evident that if an ape's skull is to be regarded as in the line of man's ancestry it ought to be older than the oldest known human skull" or older than the implements made by humans. Now there can be no doubt that stone implements occur in deposits from Middle Pleistocene time onwards, and while Broom and others assign such creatures as the Taungs and Sterkfontein apes to the Middle and Upper Pleistocene respectively, it must be understood that it is possible that these fossils are only in the line of human ancestry in that they are survivals of ancestral forms and can in themselves not therefore be ancestors of the human race.

I must therefore repeat that if Broom's estimate of the age of the Taungs and Sterkfontein apes is correct, or even reasonably approximate, then these creatures lived in the Union side by side with men who made a variety of highly developed tools. The very caves in which their remains are found may have been visited or occupied by man, and the fossil bones found in these caves may represent all that was left of the meals these men enjoyed and not, as has been suggested, the remains of creatures killed by these man-like apes or some more fearsome creatures. Indeed it was my extreme good fortune last year to discover remains of human industry and a mass of mineralised bones in typical hearths in and under twenty feet of a breccia-filled limestone cave in the Central Transvaal. Whether this fossil and implement-bearing breccia is the same age as that at Sterkfontein or not we cannot yet say, for an opportunity to carry out a proper excavation has, unfortunately, not yet arisen, but thanks to prompt action on the part of our Commission for the Preservation of Natural and Historical Monuments, Relics and Antiques, the willing co-operation of the owner, Mr. J. H. Hamilton, of "Cedarmont" near Standerton, and the generosity of Mrs. Alice Bowler-Kelley, of

Paris, who provided funds for fencing and other protective measures, the caves have been legally and adequately protected against exploitation. The occurrence is an impressive one and may yet provide most valuable information about the activities and associates of early man in this sub-continent (22).

Like its precursor, the First Wet Phase, this Second Wet Phase did not last. It witnessed a spectacular evolution of human industry and is notable mainly on that account. The rains of this phase ultimately decreased in an alarming manner, and a prolonged dry spell of unrecorded severity set in. The climate became completely arid. Dry winds from the west swept up the sand of the Kalahari and deposited it over thousands of square miles in the basins of the Orange, Vaal and Hartz Rivers. Over a hundred miles east of the present limits of the Kalahari we find deposits that occasionally reach a thickness of twenty feet. The climate generally must have been most inhospitable, and man can only have survived with difficulty. The intermittent rains eroded the old land surface and the stone tools that were exposed were deeply oxidised. This oxidising process frequently gave rise to crusts that penetrate as deeply as a quarter of an inch into the body of the tool.

With the passage of time, however—that is the nearing of the end of the Upper Pleistocene—the rains again increased and the Third Wet Phase set in. In intensity it was as marked as its predecessor. The rivers and streams were revived, further erosion followed in certain areas and in others grits, sands and clays were deposited over the older beds. It is in these deposits that we find the tools of man of advanced Upper Pleistocene times. In addition, we have the mineralised remains of a fauna not yet entirely extinct, and for the first time, the fossil bones of humans who lived during this phase, but are now also extinct. The most notable of the extinct animals of this period are the Cape Buffalo (*Bubalus bainii*) and the Cape Horse (*Equus capensis*). The human remains have generally been assigned to the Boskop branch of the human family. Boskop Man, the Springbok Flats skull, Matjes River, Skildergat Cave, the Florisbad Skull (proto-Boskopoid), and possibly Rhodesian Man, all belong to this period—and all are associated with some phase or another of what is termed the Middle Stone Age. This phase of the Stone Age is very complicated, and it is possible that several races of *Homo sapiens* were in occupation of the sub-continent at the time.

The Middle Stone Age may generally be said to be based on a technique known as the Levallois. It is represented by a number of variations of the main culture complex—rude in the beginning but remarkably refined toward the end when men made a great variety of tools—beautifullly trimmed spear heads, some plain, some notched for hafting, a variety of scrapers (end-, side- and hollow), many chisel- and graver-like

tools, beautiful backed knife blades and rounded throwing stones or bolas. Hand-axes and cleavers—survivors of the distant past—were also occasionally made. These remains are found in great abundance throughout the length and breadth of the land, and generally occur in grits and lateritic beds in the sub-soil. They have also been found in certain bone breccia-filled limestone caves of the Central Transvaal.

The richest areas known are in the Central and Southern Transvaal, the Western Free State and the Cape generally, but tool types derived by the same or by a very similar technical process can be traced northwards through Rhodesia and Central Africa to North Africa and into Europe and hither Asia. Indeed, the Levallois technique was first of all recognised and named in France. Yet it and the pleasant climatic conditions that obtained in Africa while it was in vogue did not last. Again the rains diminished, and again the comfort of man and beast alike was marred by a long arid period. Dry winds carried the younger wind-borne sands and deposited these in a heavy blanket over the centre areas of the Union, while occasional rain storms eroded and peneplained the land surface. The aridity was intense on the highveld, and the flora and fauna must generally have suffered intensely. Man sought, or was driven to, pleasanter retreats, for he could only have survived this period in sheltered and watered pockets in little groups here and there.

As time passed, however, the rains again increased, until a general revival took place and man once again roamed freely over the sub-continent. But now we find a different man practising different cultures. With this final period of increased rainfall we get the first appearance of our Australoid and Bushmanoid types, and the cultures that comprise the Later Stone Age—first the earliest phase of the Smithfield or Koning, then the Smithfield and Wilton Cultures appear—preceding each other here, existing side by side elsewhere and, excluding the earliest phase of the Smithfield, which appears to be consistently early, even following each other in reverse order. There was a very general increase in human industry and movement and most outstanding of all, art came into its own. While many folk of this period continued to live in the open, others took to caves, but wherever they lived they decorated their surroundings. In the open they made pictures of the animals they saw by engraving or pecking their images in rock; in the caves they occupied they painted frescoes on the walls—often very beautifully and often throwing interesting sidelights on their customs, dress and ceremonies. Their arts and crafts continued to evolve, tool-types increased in number, and bone and wood were more generally used. The art of making pots of baked clay was also reached—but man remained the primitive hunter. He had no domestic animals and did not cultivate the soil—and thus it was that when our European ancestors first

set foot in South Africa some two and a half centuries ago, the major portions of the country were occupied by Stone Age man. Hottentots had spread down the west and along the south coast, Bantu-speaking folk had spread down the east coast, penetrating inland here and there, but the rest, and major portion, of the Union was occupied by the Bushman—the last survivor of the Stone Age in Africa.

This brings us to the end of our review. To enable you to appreciate the significance of these climatic changes and the sequence of human material cultures more clearly, we shall briefly examine the conditions that obtained in other parts of the world during the same geological period.

3. Past Climates in Other Parts of the World.

In East Africa, Leakey has recognised and named four wet phases that follow a great Lower Pleistocene pluvial, and in deposits that were laid down during these phases, he has not only found an abundance of extinct animal remains, but also a spectacular and progressive series of remains of human industry. The four wet phases have been named the Kamasian, the Gamblian, the Makalian, and the Nakuran. The Nakuran Wet Phase is best described as semi-arid, and in actuality brings us to the present. The Kamasian, Gamblian and Makalian appear to be the counterparts of our First, Second and Third Wet Phases. The fossil contents of the deposits of these phases in East and Southern Africa show remarkable affinities. The slowly evolving industries of man and the end-products of these industries during the Kamasian and First Wet Phase on the one hand, and the Gamblian and Second Wet Phase on the other are so close as to be well-nigh indistinguishable. The temptation to complete the climatic correlation is great—but we must not be impatient.

A remarkably similar curve can be plotted for Uganda, where Wayland has so successfully devoted so much of his time to an attempt to reconstruct the Pleistocene climates of that region (14). Work in the Belgian Congo (15), the Saharo-Arabian Belt (16), and the Valley of the Nile (17), also reveals several long pluvial or wet periods separated from each other by prolonged dry spells.

The whole of the Quaternary in Africa is thus seen to be characterised by markedly alternating wet and dry periods. In all the areas where considerable research has been carried out we find at least two major pluvial or wet periods separated from each other by prolonged dry periods. Within each wet phase, and similarly within each dry phase, there are minor fluctuations for each region studied. Africa is a vast area and a uniformly equal climate is not to be expected over the whole. Nevertheless, the major sequence of events is such that it can only be attributed to some common cause. When to this knowledge we add the mass of facts that have been collected

to reveal and explain the advances and recessions of ice sheets during the last Great Ice Age in Europe, and recognise the four major glaciations, the Gunz, the Mindel, the Riss and the Würm—separated from each other by milder interglacial periods (with a particularly long interglacial period between the Mindel and the Riss), and realise that a similar state of affairs existed in North America (18). Central Asia (19), and elsewhere, we are strengthened in our conviction that the best means of correlation must be sought in a closer study of the solar and terrestrial phenomena that caused these variations, and the effects of these in different latitudes.

4. Extent of Diffusion of Main Divisions of Human Industry.

Throughout the Great Ice Age, Man occupied Western Europe, and from the beginning to the end, the evolution of his arts and crafts reveals a remarkably similar state of affairs to that which we find here. In the beginning we have pre-Abbevillian in the pre-Gunz and Gunz Glacial period. The Abbevillian follows in the Gunz-Mindel Interglacial, the Lower and Middle Acheulean in the Riss-Würm Interglacial. So far as the principal tool-types are concerned, these cultures are practically mirror images of our African Abbevillian, African Acheulean, and Stellenbosch types. Like the climates, the cultures as a whole differ in certain respects, for in Western Europe the Abbevillian and Acheulean cultures are not the only ones known to have been practised during the Lower and Middle Pleistocene. There were certain so-called flake cultures (the Clactonian and Early Levalloisian) as well (20), but these and other differences do not in any way detract from the remarkable affinities that can be traced in an unbroken chain from the Cape to North Africa and then across the Mediterranean into Europe and via Palestine into Asia.

Then come those mid-palæolithic cultures that depend on, or were influenced by, the Levallois technique—in Europe as well as in Africa. These were followed by the Upper Palæolithic: the Koning and Smithfield cultures here, the Kenya Aurignacian in East Africa, the Capsian in North Africa and the Capsio-Aurignacian in Western Europe—all of which bear an obvious relationship to each other. And all these cultures as well as those that follow, from the early palæolithic to the neolithic, and the changing scenes of animal and plant life that accompany them, are set on stages that appear in turn in a curve of climatic changes that seems to be our only clue to a knowledge of the relative time horizons when these cultures first appeared on the different stages.

From the point of view of the prehistoric archæologist there is nothing to indicate man's appearance on the South African stage until he was a comparatively skilled craftsman. The oldest and crudest pebble cultures reflect a designing mind.

In contradiction we have cruder tools that have been assigned, not only to the Lower Pleistocene, but even to the Pliocene in palæartic regions. The Pliocene age of tools recovered in East Anglia for example, is very generally accepted by geologists—who must always be the final arbiters. Recently J. C. Smuts (jun.) has put forward a claim for the recognition of equally early and crude types here, and although the evidence he has produced to support his claim is striking, one should, I feel, suspend judgment until corroborative evidence is found over a wider area than that in which he has worked Excluding this claim for the greater antiquity of man in this rich cul de sac of human industry and endeavour; there is no archæological evidence that suggests that this southern extremity of the continent was ever anything more than a great storehouse of the products of men who, in a long succession of migatory waves moved southwards from greater and richer centres in the north.

The cycle of climatic changes that Smuts has worked out for the Central Transvaal during the Pleistocene is much the same as that worked out for the Southern Transvaal, the Orange Free State, and the Northern Cape, but he has gone very much further and produced a curve of changing climates and intercalated human industries for the Lower Pleistocene and Pliocene (21).

5. Correlations.

Having reconstructed the changing climates of given regions we arrive at the stage where we wish to correlate the evidence thus obtained. Before we do so, however, we must recognise two distinct groups of questions concerned with climates. In the one we deal with climatic changes in a given region or latitude, and thus with climatic fluctuations in the course of time. The recently completed geological survey of the Vaal River Basin belongs to this category. In the second we deal with the climate of a particular time in different regions. It is to the latter that the archæologist hopefully turns for the correlation of climates of a given period in distant regions. Our great anxiety is to know where and when a particular type or culture arose. Until we are able to do this on a sound basis we obviously cannot hope to trace the centre of diffusion of any given culture, the direction of any migatory movement, and still less can we hope to trace the cradle of the human race. South Africa has often been claimed as the "cradle of man" but no claim that has yet been made has been established in the light of scientific diagnosis.

The application of geological terms that refer specifically to a corner of Europe to a field as remote as this has led to considerable confusion. The bare fact of the matter is that all correlations that have hitherto been attempted have been those of palæontologists. Their criteria have been based on faunal remains only. Although the various geological periods

are each characterised by fossil remains of different organisms, and although a study of the fauna of any geological deposit may be an indication of its age, each geographical region must be studied independently and correlations with distant regions such as we have discussed this evening, must be made wth extreme caution. For example, elephants, lions, hippopotami, hyaenas and rhinoceroses have long since been extinct in Europe, but are common here to-day, and although certain European types are distinguishable from the African, yet in a few cases the living African forms are not easily distinguishable from the extinct European ones. It is possible to use the fossil remains of some of these animals for dating purposes in Europe, but it may be calamitous to extend the process to South Africa, while we confine ourselves to the field of palæontology.

The palæontological evidence may not generally provide satisfactory clues so far as the Pleistocene is concerned, yet it is the only clue we have hitherto been able to use—and that is why I have used it this evening. But in doing so, I have been fortified by the knowledge that I have also made use of the archæological evidence. When one adds this to the palæontological one's case is not quite so weak. Nevertheless, the problem of correlation will not, I feel, be satisfactorily solved until the terrestrial and solar phenomena, to which I have referred, have been more closely studied and the effects of these worked out for different latitudes.

A splendid and most satisfying lead has been given by Sir George Simpson, whose most recent contribution to this subject should be studied by all who are interested (23).

6. Conclusion.

In South Africa we are really only at the beginning of things. We have produced some most distinguished physical anthropologists and palæontologists who so far as the mechanism of the evolution of vertebrates, mammals and man is concerned have added as much as any of their day. We have an extremely rich and promising field, not only in the geological and palæontological deeps, but also in the anthropological and archæological shallows. I refer to the Quaternary—the Age of Man. That he existed here throughout by far the greater portion of this age is demonstrated by an abundance of stone implements in Pleistocene deposits.

Archæologists have done much to reconstruct the story of man's development as they see it in the gradual evolution of his arts and crafts; palaeontologists—both human and faunal—have added immensely to our knowledge, and geologists have reconstructed the story of ever-changing past climates of certain regions, but a great deal requires to be done. Palæobotanists and soil chemists must still add their quota and terms used to describe times must be more carefully used and more

meticulously defined. Nevertheless, a start of which we may well be proud has been made, and we may hope that the day is not far off when, by means of climatic correlations, and with more universally applicable terms, we shall bridge time and space and have some idea, not only of the corridors along which our prehistoric forerunners migrated, and when, and in what directions, they moved, but also some more exact idea of the centre from which they originally came* (24).

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PREFACE.

As the material dealt with in the Symposium held in Pietermaritzburg on 6th July, 1938, is of great and lasting importance to all South Africans, and carries weighty messages to all those concerned with conservation of our natural resources and with the education of the juvenile and the adult alike, the Council of the South African Association for the Advancement of Science decided to publish in pamphlet form the papers presented at the Symposium.

It is the hope of the Association that copies of the pamphlet will be read and studied with interest and with particular care by those primarily responsible for the political, administrative, scientific, economic, and educational development and welfare of our country. Naturally there is a wealth of general information in the pamphlet for all those who attempt to win a livelihood from the land: our farmers.

By resolution of the General Meeting held at Pietermaritzburg in July last, a copy of the pamphlet has been presented to the Prime Minister for his esteemed consideration.

One of the objects of the Association is to bring the spirit of, and the advances made in, Science to the general public; it is felt that the presentation of the material contained in this pamphlet is a practical step toward a better fulfilment of the Association's responsibilities in this connection.

If interest shown within and beyond the Association in the details of the subject discussed at the first *plenary* Symposium be maintained in Symposia to be arranged in the future, the publication of a Symposium Report in pamphlet form for general distribution at a nominal price, may well become a yearly feature of the activities of the Association.

It is hoped that a summary of the discussions following the formal papers will be published for future Symposia.

Enquiries regarding the last Symposium or future Symposia should be addressed to the undersigned. For sake of general information it should be stated that the next Symposium is to be held at East London during the first week of July, 1939, the subject for discussion being " The Need for the Investigation and the Conservation of Human Resources in South Africa."

John Phillips

Organiser of the 1938 Symposium,
Hon Editor of Publications.

University of the Witwatersrand,
Milner Park, Johannesburg.

CONTENTS.

INTRODUCTORY REMARKS

BY

THE PRESIDENT (Professor L. F. MAINGARD).

Ladies and Gentlemen,

My remarks will be brief. as I think it will be far more profitable for you to listen to our authorities on the different aspects of the subject of this symposium.

But before calling on the authors to read their papers, I would like to emphasise one or two points. It is the first time in the history of the Association that we have sat, for scientific purposes. in plenary session and that all the members of the different sections have thus been brought together. This marks a very important departure from our usual practice of meeting in strictly separate sections or, on rare occasions, of having two or three sections to join forces for the discussion of matters of common interest. It has been felt by many in the past that scientists have too often worked in isolation. The normal procedure of science is analytical. It has to take things separately in order to be able to study them. But a time comes. in this process of study and discovery, when it is necessary and advantageous to gather together and to co-ordinate the results which have been obtained. This is what we shall attempt to do here.

There is another object which has been in the minds of the organisers of this symposium. It is an endeavour to arouse the interest of the public generally and, more particularly, of the competent authorities, on a question of great importance and of vital significance to the continued prosperity of this country. Hence the choice of our theme to-day, viz., "The Need for the Conservation of South Africa's Natural Resources and Features of Scientific Interest and Importance."

Ladies and gentlemen, I have now much pleasure in calling on the different authors to present their papers in the proper order.

I.—Section A: Climate in Relation to the Deterioration and Conservation of Natural Resources in the Union

BY

F. E. Plummer and D. G. Haylett,

*Departments of Geography and Agronomy, University of Pretoria.**

With 9 Text Figures.

Part I.—SOLAR RADIATION.

1. Introduction.

The Union of South Africa is nearly half-a-million square miles in area. It forms a tongue-shaped peninsula with its "root" in the Torrid Zone, stretches through 13° of latitude to 35° South, and extends through 17° of longitude. 3,500 feet in average height, 58 per cent. of the country forms a vast plateau sloping gently from the Great Escarpment to the Kalahari depression, while 34 per cent. faces towards the East, South-East and South and the remaining 8 per cent. looks towards the Atlantic Ocean on the West.

2. Radiation.

Solar radiation is the basis of the whole sequence of weather and therefore of all climates (1). Yet measurements of this fundamental element form no part of the daily routine at any normal weather station, nor does it find a place in the international telegraphic code (2).

This universal and ultimate source of energy forms the largest and most accessible natural resource, uniquely available in semi-arid regions like the Union. But it has not yet been sufficiently studied for man to be able to harness it or effectively to utilise it for his economic or healthful benefit. The results of the work of Miss G. Riemerschmid, carried out under the auspices of the Union Department of Public Health with financial assistance provided by Dr. Hans. Merensky, are not yet available (3). Miss M. Matheson is reading a paper to this Congress bearing upon this important subject (4), but apart from these workers efforts nothing has been done since the preliminary observations on solar radiation carried out at the Transvaal Observatory, Johannesburg, from 1908 to 1910 (5).

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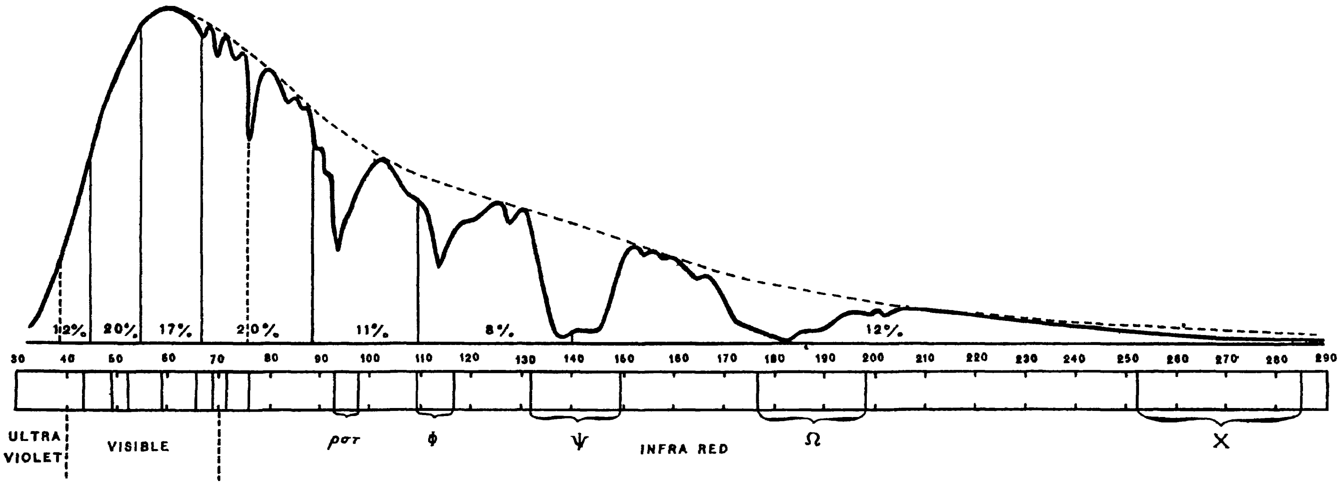
* Part I.—Solar Radiation, by Professor F. E. Plummer.
Part II.—Rainfall, by Dr. D. G. Haylett.



SOLAR RADIATION ACCORDING TO WAVE LENGTH, WITH ATMOSPHERE ABSORPTION BANDS DUE TO WATER VAPOUR.

Graph 1.

Modified from Fig. 72. Manual of Meteorology, Vol. III, by Sir N. Shaw.
(After S. P. Langley).

All higher forms of life are constrained to regulate their activities according to the visible sojourning of the sun across the sky, whilst plant- and tree- growth and crop yield are all vitally influenced by solar radiation (6). Some plants in strong sunlight become predisposed to attack by disease (7), others become more resistant, while the life histories of bacteria, insects and parasites are also affected in many ways (8).

Graph 1† shows that solar radiation is polychromatic, and that half its total energy lies outside the visible spectrum in the ultra-violet and the infra-red portions of the wave band. All these sections have received some attention at the hands of scientists, the most refrangible as well as the least refrangible rays having been successfully exploited in commercial and scientific photography. In the North Temperate Zone solar radiation has for some time been recognised as a most beneficent therapeutic agent in the prevention and cure of rickets in children (9), but recently it has also been cited as a possible cause of cancer and a contingent cause of rheumatism (10).

The amount of solar radiation reaching unit area in any part of the Union of South Africa depends upon:—

(a) the solar constant and its variations,

(b) the transparency of the atmosphere,

(c) the duration of sunlight, and

(d) the air-mass penetrated by the solar rays (11).

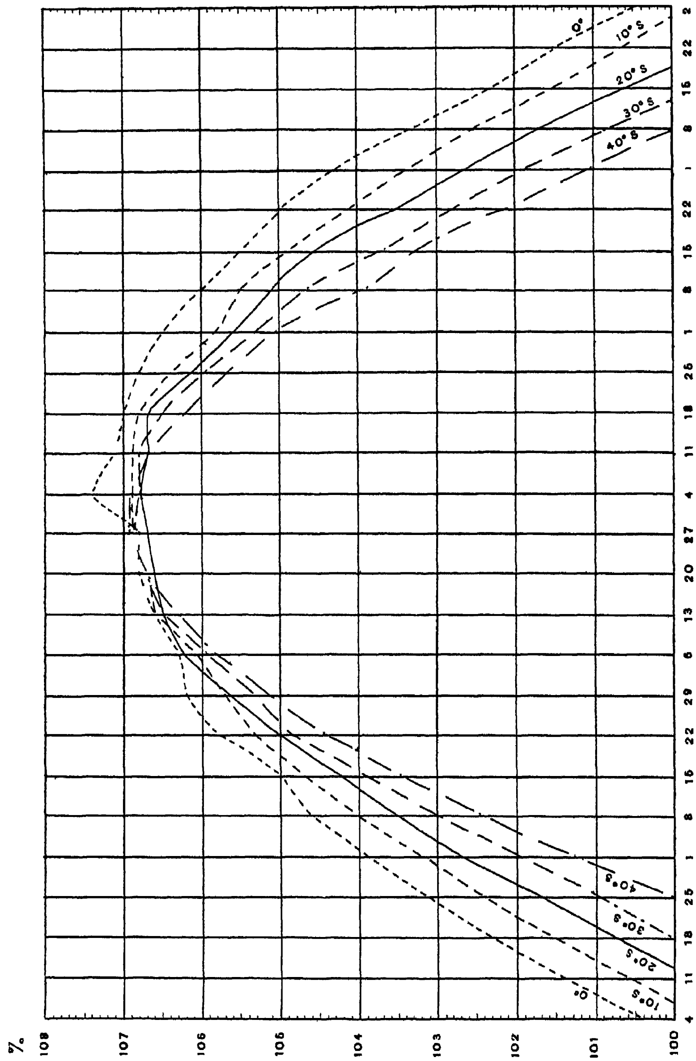
(a) *The solar constant and its variations.*

The intensity of the incoming beam of sunlight at the outer limits of the earth's atmosphere—or solar constant—averages 1·94 gramme-calories per square centimetre per minute, with a probable error less than 0·1 per cent., but both long and short interval variations have been detected, and observed changes of as little as 0·45 per cent. are considered of importance in influencing the weather in North America (12).

At times of maximum sunspot activity the solar constant is highest in value at the outer limits of the atmosphere, but induced changes in the distribution of temperature and cloudiness of the atmosphere appear to result in increased storminess and higher rainfall on the earth, so that Dr. Simpson has suggested that an ice-age might be produced by a 20 per cent. increase in solar activity (13).

Owing to the ellipticity of the earth's orbit, the earth is in perihelion 10 days after the December Solstice so that, other things being equal, Africa South of the Equator receives, from the 26th of November in any year to the 4th of February in the following year, i.e. in Summer, daily amounts of solar radiation

† I am indebted to Miss H. Bourhill for assistance in the drawing of the graphs.—F.E.P.



Graph 2.

Data from table on pp. 4 and 5, Manual of Meteorology, Vol. II, by Sir N. Shaw.

at least 5 per cent. in excess of those received in North Africa from the 27th of May to the 6th of August in any year, i.e. in the Northern Summer. (See graph 2).

Is it possible then, that the storminess, the high rainfall and, paradoxically, the popular conception of the prevalence of drought conditions over most of the interior plateau of South Africa during January are to be ascribed to the coincidence of the time of maximum annual value of the solar constant with that of the greatest altitude attained by the noonday sun in these latitudes?

(b) *The transparency of the atmosphere.*

78 per cent. of the radiant energy received from a zenithal sun in a clear sky under average conditions reach the earth's surface. The remainder is partly scattered, partly absorbed by the constituents of the atmosphere (14). From data obtained largely in the Northern Hemisphere, the effects of clouds are found to vary over a very wide range indeed. Through the added effect of sky radiation, a bright sheet of alto-stratus cloud caused a temporary increase of 40 per cent. above the normal direct solar radiation recorded on a pyranometer at Madison, Wisconsin, on the 5th of February, 1912 (15), whilst Kimball (16) states " during a severe thunderstorm at noon at midsummer the illumination may be reduced to 1 per cent. of the illumination measured with a clear sky." Relative freedom from clouds for considerable periods of days, even in the rainy summer season and almost every forenoon, leads one to form the opinion that as a factor tending to diminish the quantity and quality of solar radiation, cloudiness is not so effective in South Africa as in many other of the inhabited regions of the globe.

The transparency of the upper layers of the atmosphere renders them less absorbent of solar radiation and diminishes their rise in temperature in spite of the power of the sun's rays. Rocks and bare soil on the other hand, though poor conductors, are competent absorbers of heat and, in sunlight, the temperature of their surfaces rises rapidly. On the South African plateau therefore, throughout much of the day and night, there is a very marked difference between sun temperatures and shade temperatures, between ground and air temperatures, and there are very rapid changes in these temperatures at the times of dawn and dusk. These conditions are extremely favourable for the mechanical weathering of rocks and the production of rock waste. They also impose a heavy strain upon the constitution and powers of resistance of all life forms.

(c) *The duration of sunlight.*

Of greater significance than the varying length of the day is the imposition on the western borders of the Union of a partial " daylight-saving " scheme throughout the year on account of the central meridian of the Union Standard Time zone, 30° East Longitude, passing so close to the East Coast.

The mean daily periods of sunshine for Kimberley, Johannesburg and Cape Town are high, being respectively 78 per cent., 73 per cent. and 66 per cent. of the possible totals at those places (17).

(d) *The air-mass penetrated by solar rays.*

Assuming the air-mass above a station to be proportional to the barometric pressure registered there, the air-mass above Kimberley (3,996 feet) is 0·87 of the air-mass above Durban (at sea level), both places being almost on the parallel of 29° South Latitude. At noon on midsummer day solar rays traverse 1·01 of the depth of the atmosphere to reach Durban, but at Kimberley the noon rays of the sun penetrate less than unit air-mass for 184 successive days—from the 20th of September in any year to the 23rd of March of the following year.

Graph 3 shows the air-mass penetrated by solar rays at noon on each day of the year at the following places:—

Place.	Latitude.	Longitude.	Height.
Mpika ...	11° 54′ S.	31° 26′ E.	4,647 feet
Broken Hill ...	14° 30′ S.	28° 30′ E.	3,920 ,,
Bulawayo ...	20° 02′ S.	28° 58′ E.	4,393 ,,
Pretoria ...	25° 45′ S.	28° 12′ E.	4,350 ,,
Kimberley ..	28° 44′ S.	24° 46′ E.	3,996 ,,
Cape Agulhas ...	34° 40′ S.	20° 00′ E.	0 ,,

The graph clearly shows the influence of altitude above sea-level in increasing the amount of insolation received at a station, as the curve for Cape Agulhas is quite separate from the other curves, all of which are remarkably uniform, with almost exact equality in the amount of air-mass penetrated at noon at each of these plateau stations during the hot months of November, December, January and early February.

Graphs 4 and 5 show respectively for Cape Agulhas and for Kimberley the amount of air-mass penetrated, in units of the earth's atmosphere, by solar rays during the course of each day of the year. At Cape Agulhas the air mass traversed by solar rays always exceeds unity, and only for nine hours on midsummer day and for two hours on midwinter day is the air-mass penetrated less than twice the depth of the earth's atmosphere. At Kimberley, on the other hand, solar rays penetrate less than unit air-mass during the four hottest hours of every day from mid-November to the end of the following January.

As it is the red end of the spectrum that most easily succeeds in penetrating the atmosphere to reach sea-level, over the plateau there will be a markedly high proportion of the more refrangible ulta-violet rays, which are considered to be stimulating to both animals and man, powerful to burn the skin, and trying to the eyes.

Thus, owing to the position, size, configuration and build of the Union of South Africa, the quantity and quality of solar radiation may be expected to be considerably greater over a larger area than in any land situated in the same latitudes North or South of the Equator.

In view of these considerations, it is our considered opinion that further, closer and more detailed study of the incidence of solar radiation in South Africa should be instituted without delay, and that the work should be carried out in direct relationship with the meteorological, biological and economic needs of the country.

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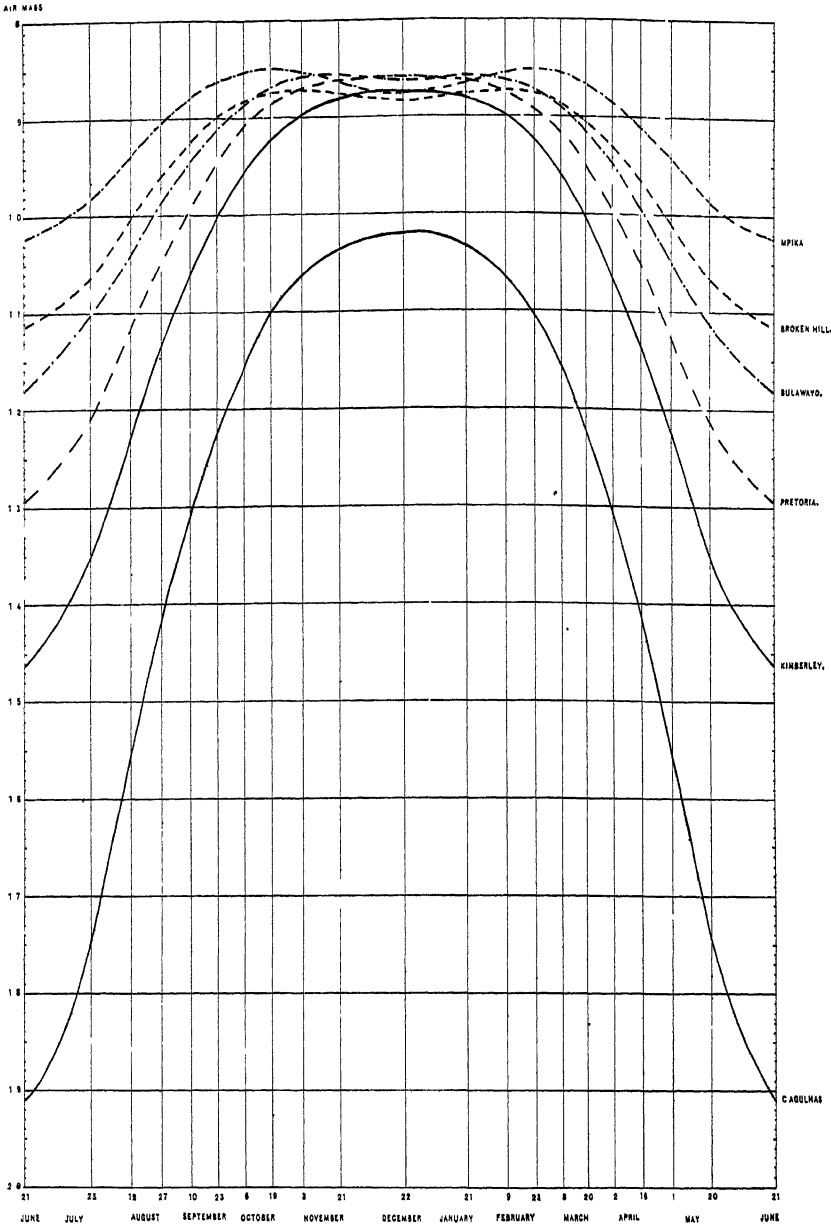
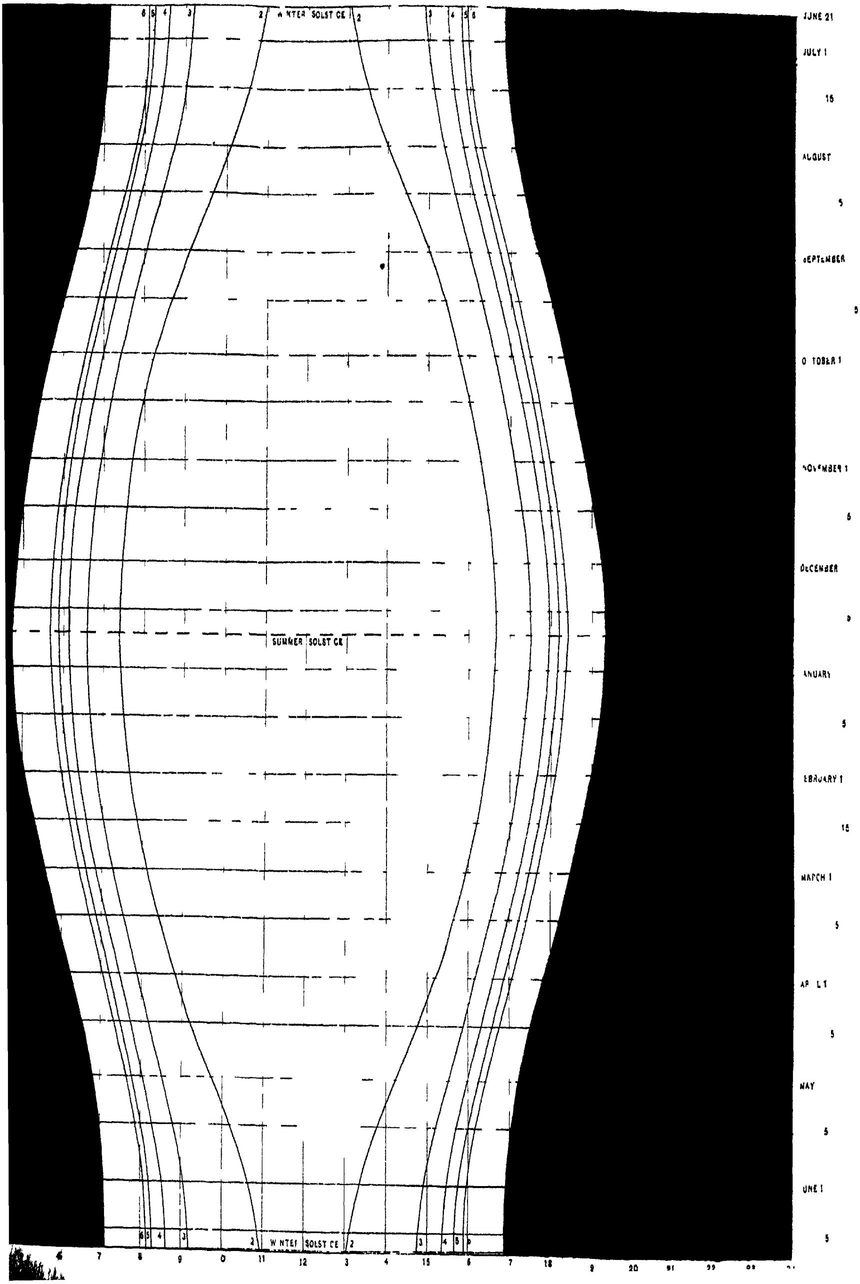


AIR-MASS PENETRATED BY SOLAR RAYS AT NOON

Graph 3.

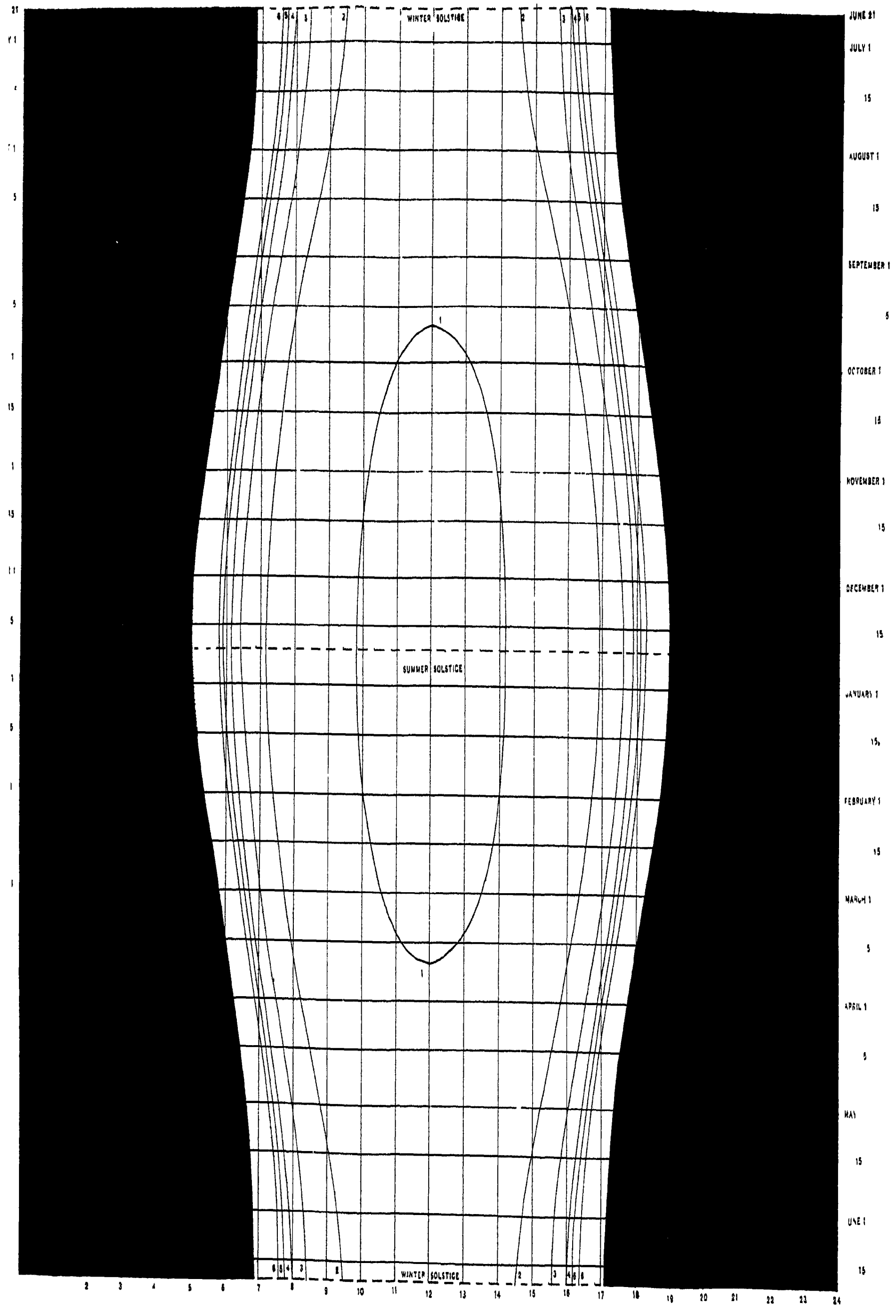
Data supplied by the Meteorological Office, Pretoria.

Graphs 3, 4 and 5 to face Page 400



Graph 4

[redacted] the Cape Agulhas (The figures below the graph indicate the hours from midnight to midnight)



Graph 5.

Air-mass penetrated by solar rays during each day of the year at Kimberley. (The figures below the graph indicate the hours from midnight to midnight).

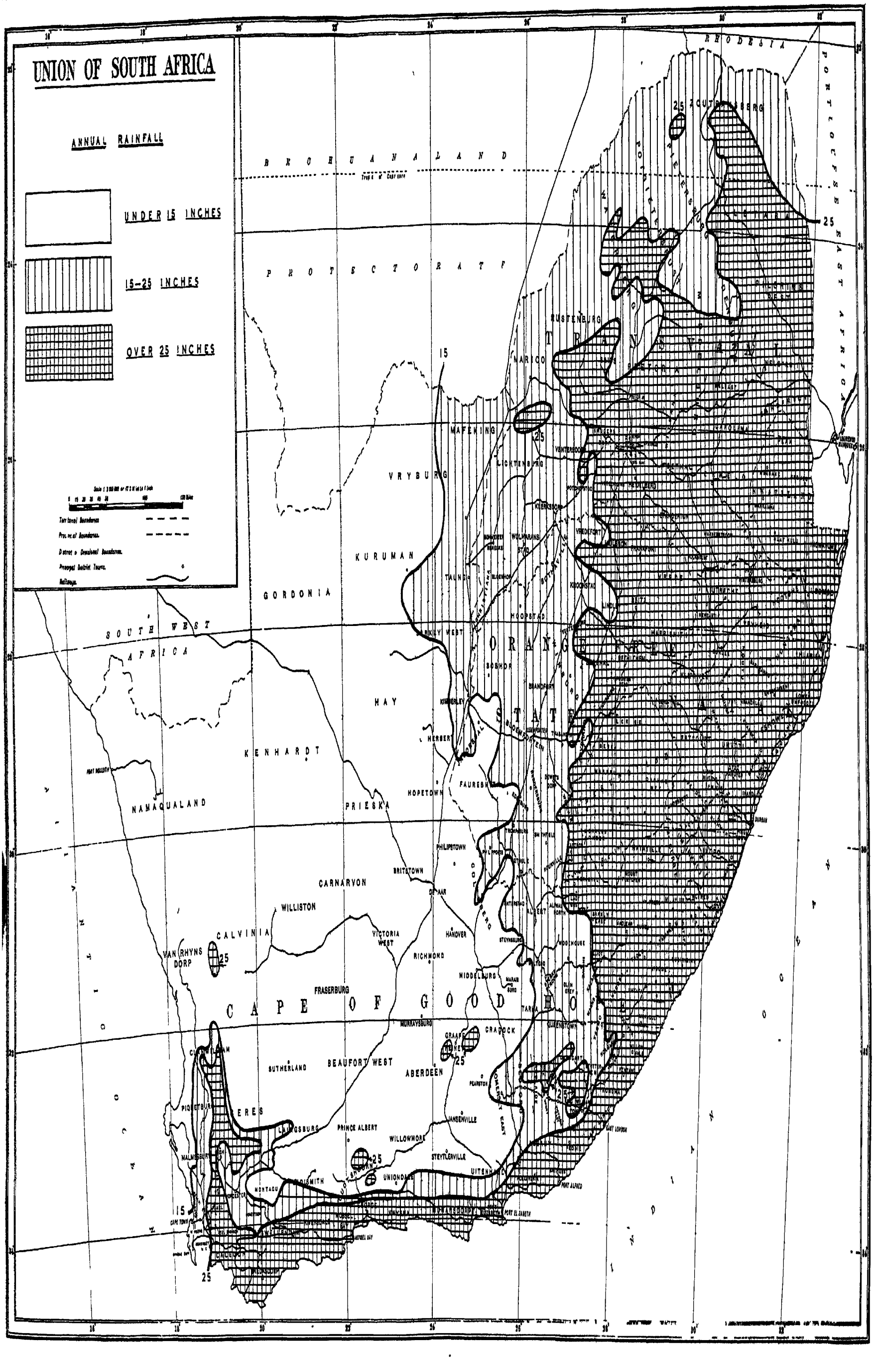


Fig 1

To face Page 461

Part II.—RAINFALL.

A. Characteristics of South African Rainfall.

1. *Annual Rainfall—Amount.*

A preliminary picture of rainfall is generally obtained from a consideration of the available mean annual rainfall data or the rainfall *normals* (9) so-called. The distribution of total rainfall will be noted from the accompanying map (Fig. 1). The mean annual rainfall over the Union is about 19 inches. About half the surface of the Union receives less than 15 inches of rain per annum, three-fourths less than, and a quarter more than 25 inches.

The *mean annual rainfall* or the *rainfall normal* at any particular locus is by no means a very rigid constant in the sense that departures from the *normal*, above or below, are relatively small and negligible. In the United States of America, Ayres (1) states that in a period of one hundred years a single year's record may vary as much as 50 per cent. above or below the mean. In the Union of South Africa, during a period of one hundred years at the Royal Observatory, Cape Town, the maximum variations above and below the normal in any one year were 33·5 per cent. and 65·6 per cent. (1930 and 1878) respectively.

2. *Variability and Reliability.*

The dispersion of individual records about the estimated mean gives a measure of variability. In this manner, Plummer (6, 7) investigated the variability of the rainfall in the Transvaal and the Western Cape Province. Plummer treated yearly records as individuals of a population distributed normally about the so-called *general mean* as the parameter. The *general mean* as defined by Plummer was in fact an adjusted arithmetic mean which allowed for asymmetry of the distribution. The question at once arises as to whether the arithmetic mean (or some adjustment thereof) can be accepted as a valid parameter of an assumed normal distribution. In other words, does the arithmetic mean tend to approach a fixed value as the length of the series of records becomes great?

Apart from the question of strict validity of the application of the mathematical process to this type of data, Plummer's results revealed some extremely useful approximations which are a distinct contribution to our concept of the variability, and conversely the reliability of South African rainfall.

This work has shown clearly that the terms *rainfall normal*, and *average annual rainfall* are descriptive of the yearly rainfall which may be expected at any selected station only within relatively wide limits. That is to say, the nature of the South African rainfall is inherently subject to a high degree of variability and consequently (low reliability). Variability as estimated in this way depends also on a very approximate knowledge of the true parameters which characterise the universe of rainfall observations.

3. *The Fixity of the Normal.*

The question naturally arises as to whether the *mean annual rainfall* or the *rainfall normal* tends in fact to approach a fixed value, or in statistical terminology whether it is a valid estimate of a parameter about which an infinite population of records is distributed according to mathematical law.

Is, for example, the value of a normal derived from say, one hundred annual records likely to be truly characteristic of the mean annual rainfall over a period of say, 10 centuries? This obviously is a statistical problem involving the theory of sampling and can only be solved by a critical examination of actual data.

The longest series of observations recorded in the Union are those at the Royal Observatory, Cape Town, which date from 1838. If these data (1838-1937 inclusive) are plotted in the form of a historical diagram (Fig. 2) and the straight line trend fitted, it will be found to have a slope of $-0{\cdot}0225$ inches per annum. The probability of this regression co-efficient not being due to chance variation is given by a probability value of between 0 2 and 0·3. That is to say the odds against this trend being due to chance are only about four to one, which are clearly not significant.

This evidence suggests that at least for Cape Town (Royal Observatory) the normal derived from 100 years of records, 24·58 inches, appear to be a fairly stable quantity. Whether or not this is the case for other stations has not yet been demonstrated.

The question of fixity of the normal has given rise to much scientific and popular speculation on the issue as to whether or not the rainfall of the Union is diminishing. It is accepted that during geological time, marked changes of climate have taken place over large areas of the world. There is no reason, therefore, to deny that changes either upward or downward may be taking place to-day. Such changes, however, as revealed by existing records, are probably random in nature due to the interaction of a multiplicity of factors, cosmical, geographical and meteorological, the resultant of which determines the rainfall. There does not appear to be any conclusive evidence as to whether changes of this nature are permanent—the term permanent, being used in a relative sense. Permanent changes in rainfall, if they exist at all, are probably too slight to be detected with reasonable certainty from such meagre records as are available at the present time, even outside the Union.

4. *Short Time Fluctuations.*

If the records from which normals are estimated are relatively short, the estimated value of the normal is bound to depart materially from any fixed parameter which may exist.

A number of investigators have studied the question of rainfall cycles, but as far as we are aware, no regular periodicity has been demonstrated in South Africa or elsewhere. If periods of wet and dry years were found to alternate in some predictable manner.

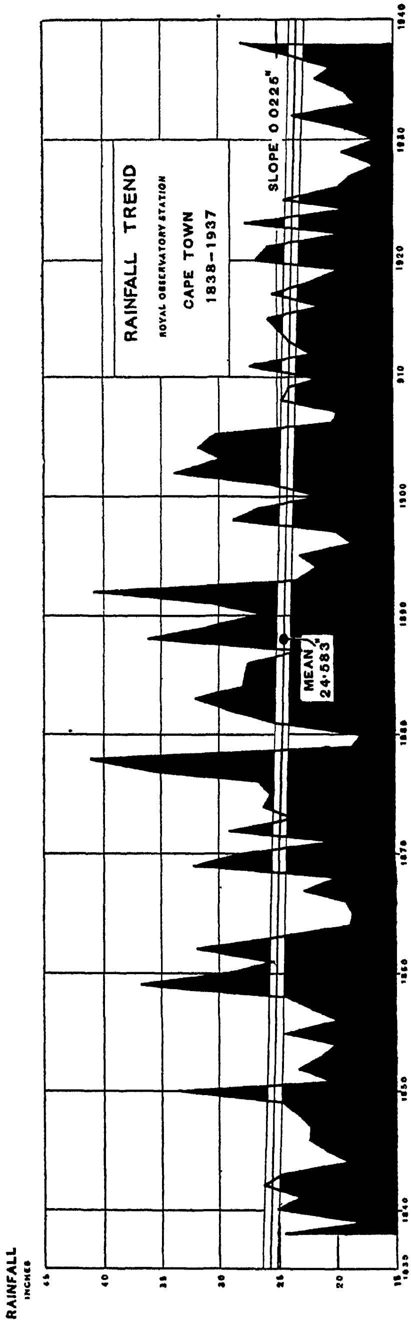


Fig. 2.

Annual Rainfall, 1838-1937, Royal Observatory, Cape Town.
(From records supplied by Prof. F. E. Plummer).

the value of this knowledge in adjusting farming operations would be enormous. The fact that periodic variations fall within the experience of a single lifetime; has no doubt contributed to the popular conception that South Africa is rapidly becoming dessicated.

5. *Seasonal Distribution.*

The seasonal distribution of rainfall is indicated on the accompanying map (Fig. 3). It will be noted that there are three fairly distinct zones:—

(a) The winter rainfall area.

(b) An area of all-the-year rainfall.

(c) The summer rainfall area.

There is obviously no clearly defined boundary between these zones, but the accepted distinction between (a) and (c) is whether or not 50 per cent. or more of the annual rainfall occurs during winter or summer respectively. The area of all-the-year rainfall is represented on the map as a transition band which stretches roughly from NW to SE on either side of the 50 per cent. line. Due attention should be paid to the extremely seasonal nature of the South African rainfall when this is considered in relation to the conservation of natural resources.

6. *Distribution Within the Rainy Period.*

Contributions to our knowledge of distribution of rainfall within the rainy period have been published by Plummer and Leppan (6) and Plummer (7). Reference to Fig. 4 shows for the Union the distribution of rainfall within the rainy period. There is no fixity about the distributions except that in a general way the form of the curve is bell-shaped, more or less asymmetrical, often multimodal. The effect of the distribution of rain within the growing season has a profound influence on the development and productive capacity of the natural vegetation and agricultural crops. Haylett (3) has investigated certain phases of the seasonal distribution of rainfall in the Transvaal in relation to the so-called critical period in the growth of the maize plant.

7. *Intensity per Rainy Day.*

There is little doubt that one of the main characteristics of the rainfall which has a bearing on the conservation of one of our greatest natural resources, the surface soil, is the intensity of precipitation during short periods of time.

The problem of rainfall intensity was investigated by Thompson (11), who measured intensity by dividing the total rainfall in a year by the number of days on which rain fell. "This figure," according to Sir John Russell (10), "really corresponds to the product of rainfall intensity and the number of hours per rainy day during which rain fell." In fact Thompson's measure is an index of mean intensity over a period of a year. From the

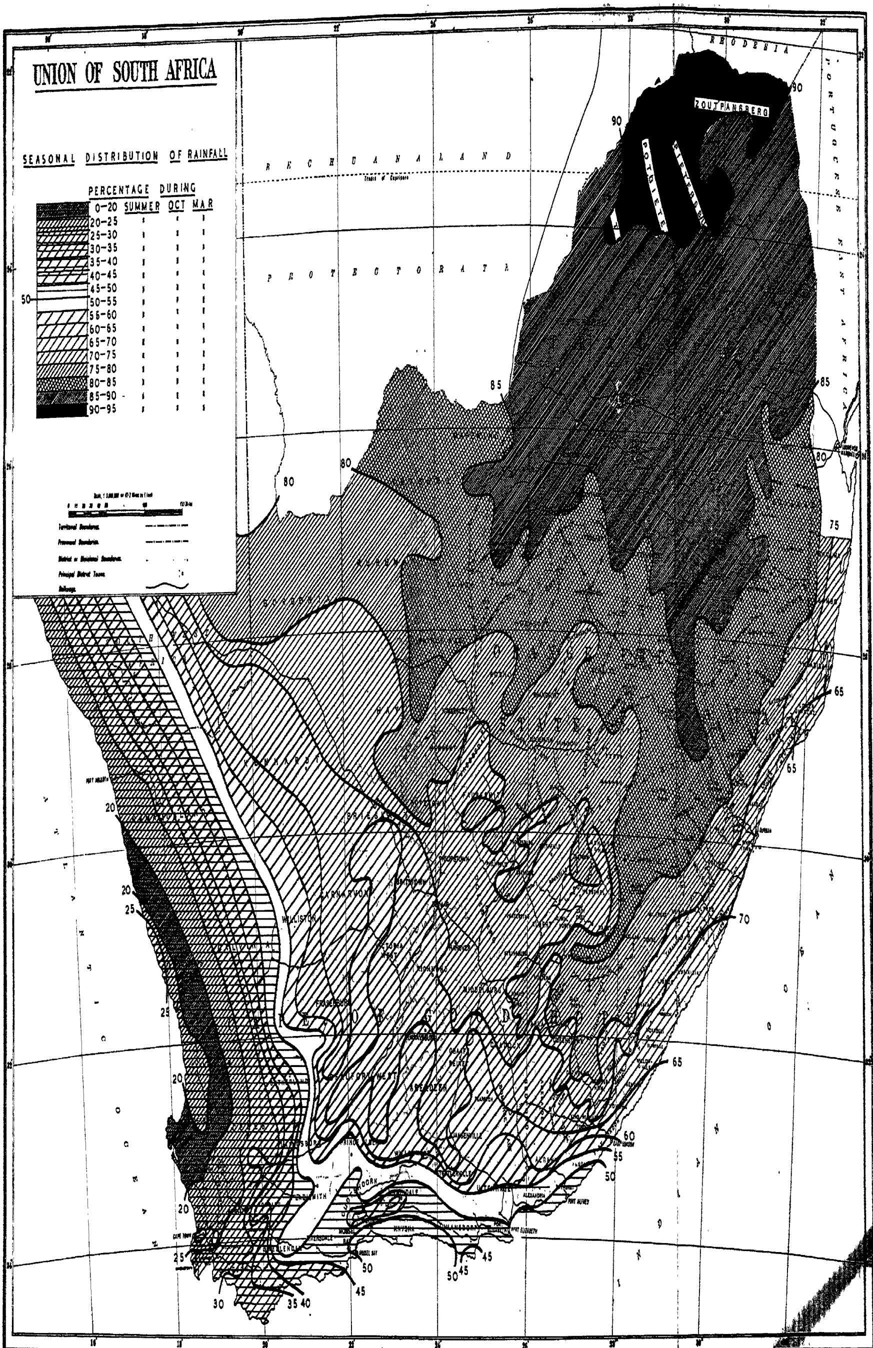


Fig. 3.

res 3 and 4 to face Page 161

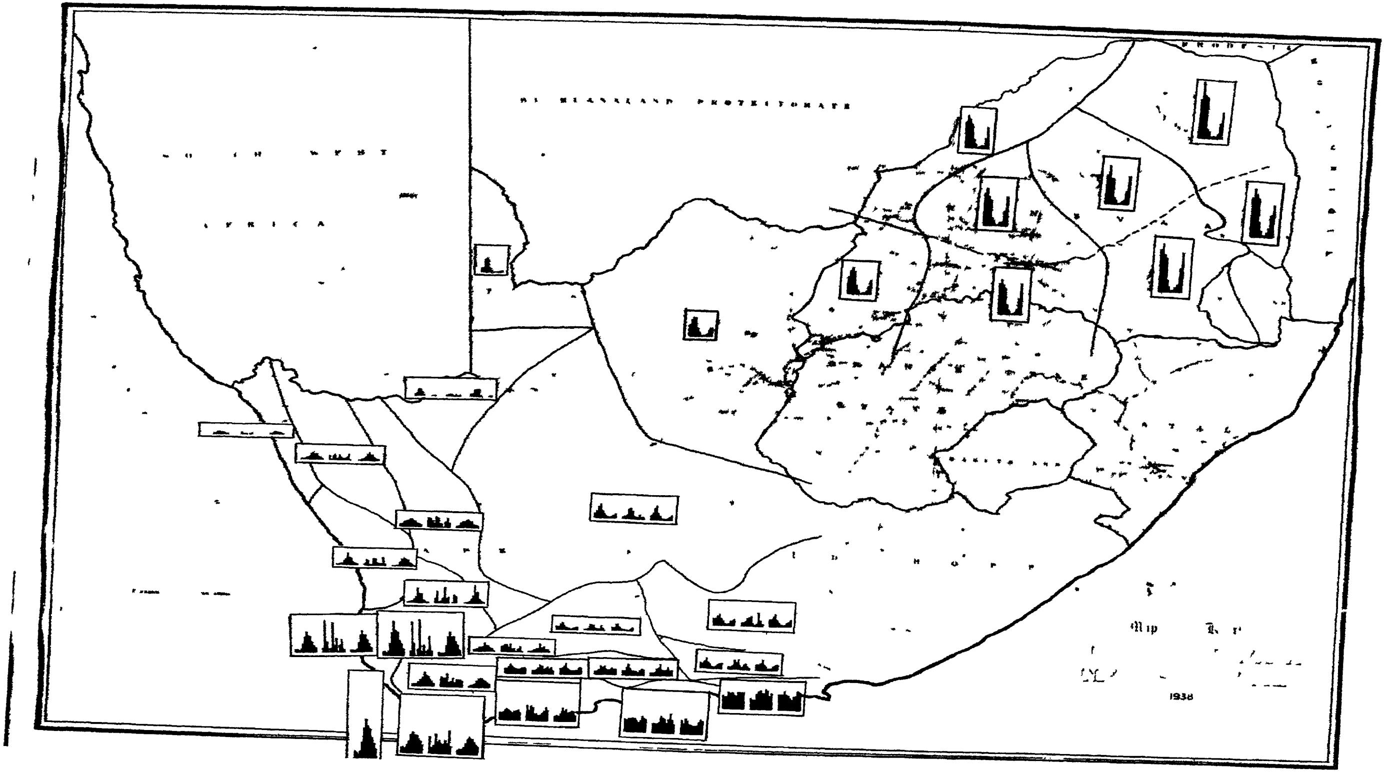


Fig 4
Monthly Distribution of Raintall (Figure supplied by Prof F E Plummer)

point of view of run-off and soil erosion, this measure is relatively less importance than the actual intensity during a shorter period of time, for example, during a heavy downpour. The arithmetical process of distributing the totality of precipitation equally amongst the number of rainy days has little direct bearing on the important relationship between what might be termed "storm" intensity and run-off.

It is a well-known fact that the rainfall in parts of South Africa occurs in the form of heavy torrential downpours during a few hours. The phemenon is too well-known to necessitate the presentation of quantative data.

B. Dissipating Factors Affecting South African Rainfall.

The nature of the rainfall and the manner in which it reaches the South African soil, was outlined very briefly in the foregoing paragraphs. It must be remembered that of the total or *potential* precipitation only a fractional part is what might be termed *usable* rainfall in the sense that it can be utilised for the benefit of man either directly or indirectly.

The potential rainfall is subject to the modifying action of a number of dissipating factors bringing about losses in effectiveness. These losses are all the more significant when it is remembered that the volume of rainfall spread over the Union as a whole is in itself comparatively low and its distribution is most irregular and erratic. These dissipating factors require our passing attention.

1. *Evaporation.*

The phemenon of evaporation is based on physical laws relating to vapour pressure gradients. Whenever a difference in vapour pressure exists between two masses of air there is a transfer of moisture from the region of the higher to the lower vapour pressure. The rate of transfer is proportional to the gradient. Two well-known states are involved in this concept which are known as relative humidity and temperature. The percentage of relative humidity of the atmosphere at a stated temperature may in fact be expressed summarily in terms of vapour pressure.

Owing to the fact that high temperatures prevail evaporation is generally high over large areas of the Union. Thus evaporation is one of the major factors reducing the efficacy of the rainfall.

From a meteorological viewpoint, relative evaporation is usually measured in inches of water lost from a free water surface under certain standard conditions. The following table gives a few figures which will enable us to compare the rates of evaporation at selected localities in the Union.

Average Annual Evaporation, Free Water Surface, at Selected Stations in the Union, after Thompson (11).

Station.	Period.	Evaporation (inches).
Kimberley	1913—1917	87·65
Bulawayo	1913—1917	74·93
N. Transvaal	1926—1929	74·28
Germiston	1933	71·46
Potchefstroom	1933	69·77
Kroonstad	1933	69·55
Johannesburg	1913—1917	61·21
Pretoria	1930—1937	59·02*
Piet Retief	1933	52·99

* Amended figure from Progress Report, Soil Erosion and Grassland Experiments, 1937 (8).

Evaporation proceeds not only from water surfaces freely exposed, such as dams, rivers, droplets on leaves and the like, but also through microscopically small apertures, provided a vapour pressure gradient is established. Such evaporation takes place from the surface of the soil, and through the stomates of plants in a form known as *transpiration*. An interesting paper discussing the physics of evaporation from the viewpoint of vapour pressure gradients, and in relation to transpiration by plants, was published recently by Curtis (2).

2. *Transpiration.*

The biological process known as transpiration relates to the loss of moisture through the plant. In fact, it might be looked upon as "biological evaporation." According to Thompson (11) lossess occurring in a field of maize at the University of Pretoria Experimental Farm would be approximately as follows:—

Loss due to—	Percentage of Annual Rainfall.
Transpiration	50
Evaporation from Soil	35
Run-off	15
Percolation	0

3. *Percolation.*

The immediate fate of rain falling on a soil is that it may either be absorbed or it may run off. Water when absorbed by a soil may exist in three states, as (a) *combined* or *unfree water*, as (b) *capillary water*, and as (c) *free* or *gravitational water*. The gravitational water rapidly drains off under the action of gravity and in the free-flowing state is known as drainage water. It should be noted that after a foot layer of surface soil, for example, has become saturated, excess water beyond the absorbtion capacity of the foot layer may percolate to a depth beyond one foot. If such water were drained off it would constitute a loss; but if the second foot of soil is dry it could absorb the water which has percolated through the first foot in which case there

would be no drainage loss. The question of moisture loss by percolation is thus relative.

Results from lysimeter experiments at the Experimental Farm, University of Pretoria (8) have demonstrated that at a depth of four feet under a crop of maize or four and a half feet under grass, no appreciable free water has been recorded. A small amount of drainage water has been recorded annually at a depth of 5½ feet on a bare soil. The absorbtive capacity of the soil with plant cover, actively transpiring and thereby bringing about a reduction in soil water is sufficient to ensure that no loss by drainage will occur under conditions prevailing at Pretoria.

We can assume therefore, that losses as drainage water are likely to be relatively unimportant in South Africa on soils where the water table is low, the soils relatively deep, and where vegetable cover is present. In parts of Europe and America percolation often exceeds 50 per cent. of the annual rainfall.

4. *Run-off.*

The most important dissipating factor in the make-up of the South African rainfall, as in many other parts of the world, is the so-called run-off. Fundamentally, run-off depends on the time-absorption capacity of the soil. When a soil cannot absorb more than a given quantity of water, surface run-off takes place and a free flow of water results. This time factor is an all-important concept to be borne in mind in dealing with run-off. The time factor embraces an interacting system based upon rainfall intensity and rate of absorption by the soil. The question of amount, intensity and duration of rainfall has already been referred to; the absorbtive capacity of the soil now requires brief mention.

(a) *Slope.*—The slope of the soil influences the rate of absorption by imparting velocity to run-off water. The reduction in velocity of run-off water is fundamental to effective soil erosion control.

(b) *Nature of Soil.*—Soils may be divided into two main types, erodable and non-erodable. The terms are relative and the quality which they describe depends largely on the time-absorption character of any particular soil. An extensive investigation by Middleton (4) has shown that the chief physical characteristics of the soil upon which erodability depends are the dispersion ratio, the colloid content and the moisture equivalent. The dispersion ratio relates to the ease with which soil particles may be dispersed under the action of water, and the colloid content and moisture equivalent are measures of the capacity of the soil to absorb water. Musgrave (5) who studied percolation and run-off losses in America by means of lysimeters, expressed the rate of absorption in "inches per hour." According to Musgrave the upper and lower limits in absorption rate were about 0·75 inches and 0·10 inches per hour respectively.

(c) *Effect of Plant Cover.*—The effect of plant cover on surface run-off is to reduce run-off (a) in respect of the total quantity,

(b) in respect of velocity and (c) in respect of the amount of suspended solids in the run-off water. Ayres (1) has attempted to summarise the effects of vegetation on run-off in the following terms:—

"1. Direct dispersion, interception, and evaporation of falling rain drops by the foliage of trees and shrubs.
2. Transpiration, through the body tissues and leaves, of vast quantities of moisture from the sub-soil back into the air.
3. Protective shield afforded by close-growing grasses and cover crops against violent impact of rainfall.
4. Knitting and binding effect of root systems in surface layer of soil simulating a sponge-like action.
5. Penetration of roots throughout the soil profile, which decay and leave numerous tubular cavities to promote infiltration.
6. Improvement of soil structure by additional organic matter increases of absorption, and keeps the soil in a condition to support vigorous growth.
7. Increased surface friction reduces volume of run-off and decreases velocity of remainder.
8. Surface friction tends to keep water spread out laterally and thus delays the rate of accumulation in tributary drainage ways."

In view of the preceding remarks it is of interest to compare the effects of different types of plant cover on run-off and soil erosion recorded at Pretoria (8) and at Missouri (12) in the United States of America. The data are summarised in the following table:—

Relative Effect of Plant Cover on Soil Erosion and Run-off.

Missouri, U.S.A.: Average, 14 years; Slope, 3·65%; Plot size, 90·75 x 6 ft.; Rainfall, 37 ins.			Pretoria: Average, 6 years; Slope, 3·75%; Plot size, 100 x 6 ft.; Rainfall, 20 ins.		
Type of Plant Cover.	Run-off. %	Soil Eroded Tons per acre per annum.	Type of Plant Cover.	Run-off. %	Soil Eroded Tons per acre per annum.
Fallow (ploughed 4 inches) ...	30·7	41·6	Fallow (ploughed 6 inches) ...	25 7	10·2
Fallow (ploughed 8 inches) ...	30·3	41·1			
Maize, continuous	29·4	19 7	Maize, continuous	20·1	8·1
Bluegrass Pasture	12 0	0·3	Veld, grazed ...	7·5	1·4
			Veld, undisturbed ..	0 5	0·0

These data illustrate clearly the fact that the type of plant cover plays an important part in preventing run-off and soil erosion. Where the land is continuously covered with growing plants the relative reduction in run-off and erosion losses are, to say the least, striking. It is obvious that if natural plant cover had not been effective in preventing erosion during past centuries, all our arable land would have been deposited in the sea! The conservation of soil moisture depends on the efficient maintenance of plant cover in some form or other.

C. Conservation of Water Supplies.

While it is not the purpose of the present paper to discuss irrigation as such, we would like to draw attention to the fact that the conservation of water which is normally lost in the form of surface run-off is one of the most vital aspects in the conservation of one of the most important natural resources of the Union, namely, rainfall.

Noteworthy progress has been made in the beneficial utilization of run-off water by means of the several national irrigation schemes located in various parts of the Union. The development of smaller conservation schemes by private and State-aided individual effort are important facets in the scheme of national water conservation. These should receive further support and encouragement as much still remains to be done.

Summary.

1. The nature of the South African rainfall has been described and discussed in order to illustrate its salient features and shortcomings with a view to assisting the discussions of this symposium.

2. The review of the rôle played by the so-called dissipating factors has served to emphasise the fact that the main losses in rainfall are due to transpiration, evaporation and run-off, in this order.

3. The expectation of fruitful results of man's efforts in reducing these losses is limited largely to the aspect of the control of run-off water. This in turn is the basic factor in soil erosion. And fortunately for mankind, though not always appreciated, the growing plant is the means whereby this control can be applied most effectively.

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II.—SECTION B: GEOLOGICAL AND SOIL CHARACTERISTICS IN RELATION TO DETERIORATION AND CONSERVATION OF NATURAL RESOURCES, ETC., IN THE UNION

BY

ALEX. L. DU TOIT,
Johannesburg.

INTRODUCTION.

The time available being limited, I shall have to confine my remarks to the admittedly restricted subject of the geological aspects of the soil, yet not so much its evolution, as its preservation under conditions brought about by agricultural practice in South Africa, though frankly it is difficult to add materially to this harassing problem, on which so many strictures have been uttered or written by more competent critics.

Flying between Durban and Johannesburg less than a year ago, I was truly horrified by the picture presented of an aridity, coupled with an erosion in parts, almost as bad as any that Tanganyika could show. True, such was one of our so-called years of drought, supposedly occasional, but perhaps not far removed from endemic. That the low rainfall was not the dominant factor was brought out by the marked differences in the veld conditions on adjacent farms, showing that over-grazing was a powerful contributor to this desperate state of things. And, alas! in spite of all warnings, there seems to be no appreciable improvement, only a progressive deterioration of veld with temporary recoveries during favourable years, due in some

degree to the remarkable recuperative nature of the veld, though possibly more to the mortality of stock during the drought or during some epidemic.

At the same time it will be instructive to put oneself in the position of the farmer, who seeing, hearing or reading of the normal, not to mention remarkable achievements of intensive agriculture in Europe and other lands, and being urged to do likewise, is puzzled and distressed by the unexpectedly different and obviously inferior conditions evinced in his neighbourhood and by the difficulties he faces in trying to surmount each season of sub-normal rainfall. Seeking why such should be the case, we must largely traverse ground covered by my presidential address to this Association at Port Elizabeth in 1934.

It happens, first, that the Union is situated in proximity to the Tropic of Capricorn, that is to say, in the Southern High Pressure or Anticyclonic Belt, and secondly, that it stands at a mean altitude above sea-level of several thousands of feet. Normally therefore the atmospheric humidity is moderate to low, the air currents dry, the rainfall unreliable over appreciable areas and evaporation and transpiration losses considerable. These factors have vitally influenced the evolution of the soils and of their vegetal covering, upon which agriculture, using that term in its widest sense, is dependent.

The Soil and its Attributes.

Elsewhere I have pointed out the disturbingly small thickness of the fertile superficial zone or true soil—otherwise the Upper, Eluvial or A layer—resting on the variable and relatively infertile subsoil—otherwise the Lower, Illuvial or B layer—coupled with rather common defects, such as a low humus, nitrogen and phosphoric oxide content. The infertility of this lower stratum is well disclosed by old cuttings or borrow-pits.

Within sub-tropical soils, such as ours, chemical and bacterial reactions proceed not only faster than in temperate ones, but on somewhat different lines, more particularly in those regions having contrasted seasons. As Vageler has so ably expounded, such will result in the development of anomalous soil-types. The small humus fraction, which has a highly important function as the carrier of plant foods, is more readily decomposed, especially in bare ground, and is converted into humus charcoal. In certain environments the phosphoric oxide becomes attached to the humus or to the ferric hydrate and is then not so readily available to plants. In the process of rock-weathering in a warm climate hydrolysis of the silicates takes place with the removal of bases and partial removal of sesquioxides, which in the dry seasons may, together with some of the silicic acid, be passed upwards in the colloidal state and irreversibly coagulated, thus crowding the A layer with such undesirable substances, e.g. in the Transvaal highveld. Similarly in regions

of low rainfall carbonate of lime accumulates near the surface in nodules or sheets, e.g. in the northern Cape. So arise layers of laterite (ouklip) or "surface limestone." Under heavy precipitation fine matter is washed down from the A into the B layer through the process of eluviation, which together with leaching tends to render the surface sandier and poorer. The rapid response under irrigation of the soils, of most of the arid districts is partly due to the lack of eluviation.

Following current classification, soils are either *Sedentary*, that is derived essentially from the rock beneath, or *Transported*, such as blown sand or alluvium. While both classes are well distributed through South Africa, an admixture is not uncommon, which is sometimes, as behoves a blended material, of good quality. The precise type evolved from each class is governed by (a) the nature of the parent material, (b) the climatic and (c) the geographic environment.

Soil Delicacy.

While all our farmers have acquired practical demonstration of the generally low grade of their soils, as compared with those of most well populated parts of the globe, few of them are perhaps aware of the extremely delicate nature and lack of resilience, as we may term it, of many of the South African soils. Fewer still appear to have realised what a strain can be, or is being, put by current agricultural methods upon this tender "cuticle" of the earth. The term "face of the earth" forms a most appropriate simile and, following up the analogy, we can stress the need for keeping this fair face in good trim and free from chafing, scarring or ulceration by giving it proper attention, with lotion in the shape of irrigation, skin-food in the form of fertilisers and protection from the excessive or unbalanced attack of the elements—sun, wind, rain and frost.

Like the human skin it is built up of several layers, has pores through which to breathe, is able to get rid of surplus moisture and contains soil fluids, which act the part of the arterial system, for transferring nutriment from the soil particles to rootlets. Like skin, its surface is slowly being worn away, but is being renewed from below and is thereby capable of regeneration, provided, however, that the wound made is protected from further damage and does not extend too deep or wide in which case bareness, corrosion and sterility will inevitably ensue.

Much of the damage, seen or unseen, has been unwittingly inflicted by farmers through merely following the practices of other and more favoured lands. It cannot be too strongly impressed that the majority of our soils are more delicate than the average, that they are more readily harmed and that they take longer to regenerate after being injured—and extensive damage has already been inflicted in various parts of the country.

Soil Regeneration.

The conversion of undisturbed subsoil into soil normally demands a good deal of time—apparently from one to a few decades—much depending on local conditions, though the process can be speeded up by cultivation, manuring, etc. Its slowness is best disclosed by the study of disused ballast pits and road and railway cuttings and embankments. Throughout Russia all cuttings and embankments are straightaway protected against erosion by a neat chequer-work of sods, from which re-grassing proceeds rapidly. The humble earth-worm is a valuable "cultivator," but is unfortunately not at his brightest and best in a semi-arid environment.

In Russia and Siberia I have seen black, fertile humus soils spread over an enormous region, even into areas, admittedly temperate, having less than 20 inches of rainfall per annum, and on geological formations comparable with the rather infertile Table Mountain Sandstone of Natal. There was evidence too that, wherever erosion occurred, it led to a certain amount of regeneration within a reasonable period, and in various localities gully-erosion appeared to have been killed, or at least much reduced, through the formation of new soil and consequent regrassing. Probably the long winter snow with low evaporation is largely responsible for so valuable a soil-type and so rapid a regeneration thereof, though I fancy that such is not the whole story and that bacterial agencies must be particularly potent in that territory.

It is possible that experiments may be able to devise practical methods whereby an appreciable amount of regeneration could be effected within a reasonable period, say five years or so.

An important factor in soil evolution is the slope of the surface. Experience shows that on slopes steeper than about one in ten, unless heavily grassed, the rate of soil-formation from the weathering rock will usually fail to keep up with the normal stripping of the surface through creep aided by rain-washing. On the steeper slopes soils therefore tend towards immaturity and low fertility and should not be cultivated save with special precautious, such as contour ploughing or terracing. In India, Java, China and other eastern lands, where vast areas have thus been terraced, the method has been devised to counteract the intensity of precipitation during the monsoon season and is applied to most crops and not only to rice culture. Terracing involves, however, not only much labour, but skill in stripping the soil layer from the infertile subsoil and replacing it unmixed upon the horizontal bench.

The adaptation of this useful system—employed on a limited scale in the Fish River Valley, C.P.—to Natal with its hilly topography is put forward for serious consideration.

Erosion.

Numerous writers such as J. D. Schonken, J. V. Phillips, I. Pole Evans, A. M. Champion, C. W. Hobley and, most recently,

E. P. Stebbing have detailed and deplored the serious erosion of large sections of the African continent through various causes, of which the most potent are sheet-erosion, over-pasturage, over-cultivation, soil-deterioration, lowering of water-table, grass-burning and gully-erosion, which in combination have brought certain areas to a condition approaching desert and almost or quite irreclaimable. Parts of other continents, such as the middle west of the United States have also and seriously been affected by human activities. Another and more insidious process, common in the north-east of the Union, detailed by Dr. J. S. Henkel, is sub-surface erosion, that is to say, the development beneath the soil of tunnels, which ultimately collapse and give rise to open gullies.

Quantitative estimates of the amount of erosion in South Africa are indeed startling. Based on the average proportion of silt transported by the Orange and Vaal rivers, measured just below their junction, I calculated in 1926 that the total amount of solids carried off to the sea from that basin was over fifty million tons per annum, but measurements subsequently made at the Buchuberg Dam below Prieska by Mr. S. O. Elkund (The "Star," 10/3/37) gave for the flood period of December, 1933, the astounding figure of thirty-two million tons of silt in the space of only *two weeks*. And this catchment represents only one-tenth of the area of the Union! More of such illuminating gaugings are urgently required.

We may briefly summarise the more important factors contributing towards erosion, although candidly such talk is merely a depressing epitome of the more comprehensive reviews by others, who have moreover quoted chapter and verse.

Sheet Erosion.

The harmfulness of gully-erosion is obvious and requires no stressing, whereas sheet-erosion is more insidious, caused by the washing off of finer matter and with it humus, most markedly on slopes and thereby producing a thinning of the A layer, which may affect large regions without spectacular results. Such action will be disclosed by the high proportion of sesquioxides—characteristic of the poorer B layer—near the surface, to the cropping out of calcareous or lateritic lumps or sheets and to the development of a sandy acid covering or podsol-type of soil. In the advanced stage the process may be accelerated by wind erosion. Such deterioration is apt to follow the destruction of the vegetation by over-grazing or burning.

During heavy rains the water flowing over the surface carries along some colloidal or fine suspended matter, which temporarily blocks the pores of the soil, preventing infiltration and so leading to sheet-flow, rapid discharge into streams, peak-floods and scouring. This evil can be lessened by contour ploughing, terracing or regrassing.

Deforestation.

This matter, well known to all, will be dealt with by Prof. J. V. Phillips and requires no more than reference. Many of us have witnessed the distressing consequences of the devastation of undemarcated forests in the Transkei, Pondoland and Natal, largely on hillsides facing the south, and the subsequent erosion of the steep slopes with oxidation of the humus in the thin soil remaining. In catchments so affected the stream-flow will become more variable and the flood-peaks more acute. Such is very deplorable since the proportion of South Africa that is even moderately timbered is so ridiculously small despite the good rainfall within certain belts.

Overgrazing.

Voices innumerable have been raised to point out the seriousness of this cause. It is probably best seen along the margin of Basutoland, where degrassing has led to large-scale gully-erosion which has sliced through deep soil and rubble far into the soft shales that normally form the valley sides or hill-slopes. The same is the case along stretches of the Drakensberg. I submit that it should be an axiom that no head of live-stock should be allowed to cumber the earth any longer than is absolutely necessary, otherwise it is merely wasting some of South Africa's scanty and precious grass reserves. It is moreover regrettable to see land that has become too unproductive for crops turned over for grazing without a chance of first becoming regrassed.

It is an object lesson to compare a well-occupied area such as around Vryburg with, first, the more recently settled portion nearby, cut out of the Kalahari, and, next, the poorly inhabited Bechuanaland Protectorate beyond, and to see the deterioration that has attended stock penetration. Despite its poor sandy soil and relatively low rainfall the Kalahari is on the whole consistently well grassed and shrubbed, which perhaps explains why our Government casts such longing eyes on the Protectorate with its extensive Crown Reserves. Recently I saw it stated that there was danger lest the Union become like the Kalahari "desert," but, paradoxically, the risk is rather that the Kalahari may with closer settlement become like so much of the Union to-day:

Conclusion.

To sum up, it comes to this, that in South Africa, in contrast to most temperate countries, the soil has to be treated more carefully, that large crop-yields cannot be expected, that much of the pastoral section cannot be grazed so intensively and that in the case of soil deterioration or erosion timely remedial measures must be taken and continued with more solicitude and application and over longer periods. Failing such, irreparable damage can only result.

The problem then becomes " How can such be achieved?" The territory involved is so immense and the troubles experienced are so varied and widespread and strike so acutely at the heart of our agricultural prosperity that the only practical solution would appear to be comprehensive State intervention. Four years ago before this Association I recommended that in view of the seriousness of the situation the Government should build up a special Reclamation Service to investigate exhaustively these basic and other related problems and advise thereon, to formulate the far-reaching legislation that would be demanded, to see that such regulations were duly carried out, etc. Thus far, apart from continuing its excellent anti-erosion work, the only step made has been in the provision for State assistance towards the building of small farm dams on tributary streams, and, although the principle is commendable, its application, in those cases that I have seen, has not always been satisfactory.

It is significant, however, to learn from the Press that the idea of a Department of Pastoral Research and Land Reclamation is under the consideration of the Cabinet, and I trust that this report may prove correct. I feel strongly that in so vital a matter it is the duty of the scientists in South Africa, and therefore of this Association as representative of their combined views, to press upon the Government the extreme need for rapid and strong action, so that the rehabilitation of the countryside may be commenced in earnest and on right lines. The guiding of such regeneration—unquestionably a long process—is indubitably a scientific rather than a political business. Let us hope then that there may be no further delay now that the dominating factor for such revival can scarcely be the financial one.

III.—Section C. Deterioration in the Vegetation of the Union of South Africa, and how this may be Controlled

BY

John Phillips,

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The following is a summary of an *extempore* address delivered on the above subject, at the Symposium on " The Need for the Conservation of South Africa's Natural Resources . . . ."

Nature and Fundamental Causes of Deterioration.

In South Africa there is a considerable number of different vegetation types. Investigation of any one of the main types reveals that there has been appreciable deterioration in nature,

quality and utility; such deterioration still is proceeding, and annually is becoming more and more serious, more and more of a National problem.

Let us consider several of the more important vegetation types as examples.

Our indigenous forests of *Subtropical Evergreen* nature occur in situations obtaining suitable conditions of rainfall, humidity and temperature; in instances, such situations are along the moist sea-board (as at George and Knysna, and to a lesser extent at Alexandria and in the Eastern Cape Province and the Transkei), but more frequently, our forests find their favoured habitat upon the south, south-western and south-eastern slopes of certain coastal and inland ranges.

It is clear that the area of *High Forest* has been seriously decreased in the course of the occupation of the different regions of the Union by Europeans. Destruction by fire, and in the process of " shifting cultivation " (whereby forest was cleared year after year for temporary occupation by agriculturists), as well as by removal of young growth for hut-wattles, certainly is traceable to the Native before the coming of the European. Even since European occupation, the Native has wrought great havoc in Eastern Cape, Transkei and other forests. It must be stressed, however, that the European has played an important rôle as well, in the tragedy of reduction in extent and deterioration in quality of our *High Forests*. Private forest has been exploited so severely and so ignorantly that much of it has given way to Scrub or ruined Forest; fire frequently has followed the axe, and carried the story of deterioration several chapters further. State forests, however, for a number of decades, have been protected to the best of the ability, and the financial means of the Forest Department. This Department for many years has attempted to protect forests from fire, from unwise exploitation, and from grazing; its problems have been manifold and difficult, particularly in areas where large Native populations exist—and notably in the Ciskei and the Transkei. On the whole, this Department has been successful in its fine work of protection of *High Forest*, and it is noted with interest that it is attempting to extend its protection to areas of Scrub, Grassveld and other vegetation included in some of the catchment areas of the Union's rivers. The outcome of forest destruction, however, is that oftentimes economically useless or almost useless vegetation encumbers ground once covered by *High Forest* of high water-conserving capacity and producing kinds of timber gradually becoming more and more prized for aesthetic and sentimental reasons.

Associated in the South-western Cape Province with *High Forest* is the "*Fijnbos*" vegetation (sometimes termed *Macchia* or *Maquis* on account of its superficial resemblance to vegetation of this class in Southern Europe) made up of Protea, Heaths, and a great number of other woody shrubs, and having a wonderful representation of beautiful Liliaceæ, Iridaceæ and Amaryllidaceæ.

Frequently such vegetation is the highest expression of the capacity of the environment (climatic and soil), that is, the "Fijnbos" is a final or *climax* community. In particular localities, however, where rainfall, humidity and soil permit, the "Fijnbos" is but a stage in the development of *High Forest*. For many generations Europeans—following the example of the Hottentot, Bushman and Bantu—have burned this "Fijnbos," with the object of obtaining shorter, more palatable browse for smaller and larger stock. Gradually the influences of too frequent firing, and of firing at unsuitable seasons of the year, have shown themselves. Thus, to-day the "Fijnbos" has lost, in many localities, its former representation of beautiful plants highly prized in botanical and horticultural circles, as well as certain kinds of shrubs of higher browse value. In addition, much of the organic matter has been burned out of the soil surface, and sheet erosion of this surface has ensued. Invasion, in parts, by strictly undesirable plants like the Rhenosterbos (*Elytropappus rhinocerotis*) has taken place, and augurs badly for the future. So far we have done almost nothing toward better understanding and managing of the "*Fijnbos*."

Our *Karroo* vegetation is world famous for its grotesque form and its bizarre beauty; the high nutritive value of many plants of the vast *Karroo* region has been proved by generations of sheep and goat farmers. Almost every possible attempt, however, has been made to reduce the beauty and the economic value of the Karroo. Where it has been possible to overstock, such has been practised. Where it has been possible to trample paths, later developing to form erosion dongas, this has been done. Where burning of Karroo vegetation of certain shrubby types has been possible, such burning has been carried out, and to the detriment of the vegetation. Where there have been opportunities of encouraging the development of unrequired—because unpalatable or innutritious—shrubs or succulents to the disadvantage of kinds that are of value, such have not been allowed to slip! Definitely, the *Karroo* has deteriorated in beauty, in economic value and in pastoral potential; more and more is it experiencing the evils of diminution in effective vegetation cover, donga and sheet erosion; impoverishment in physical and chemical qualities of its soils is a nature concomitant of such erosion. What have we done to understand and manage better the *Karroo*? Very little indeed, despite the efforts of several State officials.

What of our *Grassveld*? Is all well in the great expanses of *Open Grassveld* of the southern, central, and northern Orange Free State and of the southern, central and eastern Transvaal? Unfortunately we must answer that conditions are far from well, and offer little encouragement for the pastoral industry of the future. Again, deterioration has taken the form of reduction in number and vigour of the better kinds of food plants, the increase in proportion of less palatable and less nutritious kinds, a marked decrease in absolute vegetation cover upon the soil,

and a tremendous increase in sheet and donga erosion. Responsible for this alteration in cover and in quality of the Grassveld vegetation have been, *inter alia*, the practices of mismanagement of grazing veld by owners of cattle, sheep and goats, and of putting down large areas of sub-marginal land to Maize. Mismanagement of veld is the main *theme* in the *dirge* of deterioration, and depends upon the *notes* of ignorance regarding the nature, behaviour, and responses of the *Grassveld* and its main species of plants; the lack of rotational and rest systems in grazing; inadequate provision and distribution of water supplies; complete to mostly inadequate provision of additional food in the long dry season—food in the form of veld-hay, hay from grasses grown as crops, ensilage, mealie meal and other "concentrates," and failure to differentiate between the evil and the beneficial influences of veld burning. Where does the evil effect come in of attempting to grow Maize upon areas that naturally are unsuited to such, or are too far from suitable lines of transport? Areas that by nature of the rainfall (amount and distribution over the season) and the soil are capable of producing moderate to poor quality Maize in good periods only, are incapable of adequate production during the frequent years when rainfall conditions are unsatisfactory. Accordingly, Maize growing goes out of favour, land goes fallow, and is left to the slow process of healing by Nature—hampered unfortunately by such disturbing agencies as invasion of introduced weeds (e.g., Khakibos or Tagetes; Blackjack or Bidens; Kankerbos or Xanthium). While we are fortunate in having grasses like Kweekgras (*Cynodon dactylon*) in many varieties; Eragrostis spp. (Taaipol) and Aristida spp. (Steekgras) that rapidly invade and bind the soil of the fallows, we nevertheless find that it often takes many years before any but *poverty* grazing is established upon the once cropped land. If seasons are poor in rainfall and at the same time hot, it may happen that little or no grass cover is formed before the falling of torrential early thunder showers—the result being sheet and donga erosion upon the poorly protected fallow. In the same way, better land under Maize but too far removed from railhead or good transport roads, may go out of Maize, and in the process of going back to Grassveld may become much impoverished by sheet and donga erosion as well as by leaching.

I have no intention, at this gathering, of raising the whole of the issue of the policy of Maize production, treatment of Maize land, utilisation—to the best advantage of the individual farmer, of the stock of the country, and of the community in general—of the Maize produced. I do desire, however, to interpolate that our problems of soil conservation, beef production, nutrition of Europeans and Natives, and Poor-whites are closely interrelated with the problem of the wisest utilisation of Maize. Too much Maize leaves the farm, too much Maize leaves the Union, too little is the return obtained for the soil, for the stock, for the

farmer, for the community at large! The whole of our Maize policy requires thorough re-examination and basic alteration, and that early!

I shall not continue to give examples of deterioration in vegetation types; enough has been said to show that in four important types—*High Forest*, "*Fijnbos*," *Karroo*, *Open Grassveld* deterioration is making its way apace. But I must indicate that there is another form of deterioration visible in portions of the Grassveld and mixed Grass and Thorn veld of the Eastern Cape, Transvaal, Orange Free State and Natal and in the Bushveld—that of the excessive development of undesirable woody and often *thorny* small trees and shrubs, principally *Acacia Karroo* (Sweet Thorn), but in more northerly areas also *Acacia permixta*, *Acacia litakunensis* (Haak - en - steek), *Dichrostachys glomerata* (Sikkelbos) and others. Such woody growth was kept in check by grass fires in earlier days, but as increased settlement and increased grazing reduced the density and height of the grass growth, fires became less frequent, less general, and less effective in control of woody growth. Shrubs and trees, therefore, have increased at the expense of the grass, and in many places form almost impenetrable thickets, useful only as soil protectors and improvers, sources of fuel and of a certain amount of browse. Their management, by suitable thinning, and by encouragement of the grass, is strongly desirable.

What is it possible to do about this steady deterioration in vegetation cover, quality and utility, this loss of soil and chemical foods by erosion and run-off, and the rapidly increasing seriousness of the loss of water in such run-off?

Without entering into detail, it is possible to indicate the general lines likely to lead to a solution of the central problem of vegetation and soil deterioration. At the same time, it is clear that a number of the subsidiary problems will be better defined, better understood and better attacked as information regarding the central problem increases.

For sake of clearness and brevity I list the lines that appear to me to be of outstanding importance:

(1) Formation of a Committee upon which are represented the principal Departments, Associations and Institutions, Government and otherwise, directly and indirectly concerned with the problems of deterioration.

To give some impression of the range of interests involved, interests that should be represented upon such a Committee, I suggest that agricultural, pastoral, animal husbandry, veterinary, forestry, railway, road construction and maintenance, social welfare, commercial and economics officers and also special experts be appointed. Such a Conservation Committee should be directly responsible to the Minister of Agriculture, or perhaps better still, to a small sub-committee of the Cabinet. Its function would be

to investigate the most effective, the least friction-creating ways and means of assuring that all State and other Departments and Institutions concerned shall work harmoniously together. The Country does not require a special Conservation Department; to create such a new Department of State probably would create still further inter-departmental friction, still additional barriers to a practical solution of the country's needs. What the Cabinet, what the State does want, however, is that all the existing experts —both State and others—be got to work together as a team, in the greatest harmony possible. More co-operation, less inter-departmental jealousy and obstruction, more co-ordination of information won as the result of investigation from different angles, less working in water-tight compartments, more spirit of service for the common good, more burning zeal to do the task well—that is what South Africa must have. I personally believe much could be achieved in the direction of such co-operation and development of the team spirit, were a carefully selected representative and able body of men to work together to bring about this much desired result.

Such a Committee would have to work out details regarding fields of study, points of contact, matters of co-operation, and would have to make suggestions to the Government regarding the best possible means of direction work in the various fields.

Efficiency must be the motto of the Committee; no considerations of school of thought, race, creed or political belief must be permitted to colour its deliberations.

(2) We must undertake a thorough *Land Usage* survey, beginning in the most important " problem " areas. Such a survey—which would have to be carried out by carefully selected teams of workers comprising, for example, botanist, agriculturist, pastoralist, pedologist (investigator of soils), animal husbandry expert and economist—should aim at presenting information upon *productivity potential* of given areas in terms of crops, rainfall reliability, soil nutriment, labour and transport. Such a survey should provide an answer to such questions as " What should we do with such and such an area? Is it best suited naturally and by position for agricultural crop production? If so, what crops? If not, what are its possible uses? For forestry? For pastoral purposes? If for pastoral purposes, of what class, and how may such purposes best be fulfilled? If for mixed farming, what particular lines? What transport facilities require to be provided?" Naturally, various social welfare and educational matters will crop up from time to time, varying in degree of importance from point to point; all such must be noted, and must be referred to special expert committees for investigation and ultimate report.

Clearly, assistance must be obtained from selected farmers in each district or important sub-district; the opinion of such Land Usage or Planning Farmers' Committees should be taken into careful consideration. In the United States, in about 40

States, there are about 2,400 such Farmers' Planning Committees working in collaboration with U.S. Department of Agriculture officials concerned with Utilisation and Planning. But we must be certain that party politics do not enter into the selection of such Farmers' Committees in South Africa, otherwise success will be still-born.

A wisely planned survey on land usage, land values and allied subjects would tend to alter the present unsatisfactory conditions that permit unsuitable farming practices to continue, that permit, for example, pastoral land to be put down to crops and *vice versa*, and potential forestry areas to be converted to horticulture. It would also slowly tend to change popular attitude in relation to land valuation; purely fictitious values for unsuitable land would give way to valuation of intrinsic reliability.

A *Land Usage* survey, to be of any real and lasting national value, *must be done properly*. No undue haste should be permitted to mar the results, and no unwise appointments to the survey teams should be allowed on grounds of race, political belief or school of thought. *The best men, irrespective of all other considerations, must be got.* The late Professor Warren, of Cornell University, has shown that it takes many years of work, by a devoted and efficient band of investigators, to report adequately upon five million acres! Current talk of a projected survey reporting upon *one quarter of the farms in the Union within five years* is thus shown to be poorly based and far wide of the mark. While our survey in many parts of the country would not be so detailed as Warren's in New York State, it still would require far more time than five years in which to report usefully upon a fourth of the Union's many thousands of farms!

(3) The recommendations of the *Land Usage* survey should be considered carefully by the Conservation Committee, and this in turn should recommend appropriately to the subcommittee of the Cabinet.

Special legislation to put the recommendations of the various committees into effect, would have to be enacted. That such is not impossible, if the National Will is preferred to save the country, is clear from the splendid examples being seen in the United States, where special legislation is being enforced to strengthen the hands of Federal and State Governments in connection with national conservation schemes. *Fearless Cabinet action is looked for, because without it, success cannot be achieved by the experts.*

(4) Following on the *Land Usage* survey, may have to come the appropriation by the State of certain "problem" or "submarginal" areas. Unless this is done, *economic reclamation* of the areas may be altogether impossible. Reclamation of such areas under State direction—the former inhabitants working, perhaps, as tenants under expert guidance—may be possible in some instances; in others, the conversion of the areas to Game

or other Reserves may be necessary, on account of the low economic values ever to be expected.

Other tracts may have to be set aside for catchment area conservation and management—for catchment areas, unless they be covered by forest and dense scrub, require management as much as any other class of vegetation.

(5) Valuable work has been commenced by the Department of Agriculture in the direction of veld management and pasture studies and reclamation. The Pasture Section of the Division of Plant Industry—under the able and vigorous direction of Dr. I. B. Pole Evans, for years a pioneer in this field of activity—is doing fine work of a national nature. But much more is wanted. More funds, more stations, more co-operative experiments with farmers, and more men, professional, technical and lay, for the carrying on of the excellent work commenced. In a word, *we require more State support for pastoral and veld studies than we have so far been given.* State support has been given, to some extent, to certain Universities and University Colleges interesting themselves in phases of the veld conservation problem, but much more could be done. More active co-operation could be attained not only by the provision of more liberal funds, but also by the showing of more moral support on the part of the officials. Enlightened opinion in our Universities, too seldom, is called in for technical advice, when so often such advice would be helpful to the State and would be freely given.

(6) Education authorities have done very little, so far, in regard to educating teachers, scholars and the public in respect of the great problems of deterioration. A good beginning should be made in the Teachers' Training Colleges and Universities, so that those responsible for the teaching of young South Africans should realise the extent, the nature, and the national aspects of the problems. For some years I have been including a short series of lectures, supplemented by field excursions to experimental and other sites, in courses in Botany given to potential medical practitioners, school teachers, and workers in biology. I believe that such *educational propaganda of the right kind is one of the most required duties of all classes of teachers in this country.*

The radio, the film and lantern lectures supplemented by field visits to suitable sites, should prove highly effective in interesting and in instructing teachers, students and scholars.

The United States Government has made splendid use of the radio and of the talking film, in its policy of national education in relation to soil reclamation and conservation schemes of vast magnitude. One such film— "The Plow that Broke the Plains"— actually is being brought to South Africa as the result of discussions between Messrs. African Theatres, the United States Dept. of Agriculture Soil Conservation Service, and myself. This film sets a high standard of artistic technique in production, photography, interest and instruction. I should like

to see a series of films on kindred subjects, prepared for this country.

(7) I believe, further, that the good offices of the Dutch Reformed Church ministers should be solicited. In country districts much influence is wielded by the ministers, and if they could be won over to advocate rational methods of farming, management and conservation, country people, young and old, might learn the more rapidly, and thus might be led the more easily to undertake a personal, national duty.

(8) The Government has passed legislation, I understand, covering the excessive reduction of farming areas as the result of subdivision of land on the death of the original owner. Such subdivision has rarely entailed more intensive farming, but rather has spelt more intensive " mining " and ruination. It is to be hoped that the Government will be sufficiently strong to put into effect its legislative power—following, of course, upon the advice of experts. *Unless this be done, more and more movement from the farm to the town must ensue, with concomitant social disturbance and economic disaster.*

I have touched the fringe of the subject only, but the time is far gone. There is much more that could be suggested, but I think I have said enough to indicate the seriousness of the situation and some of the lines of approach we should waste no time in considering and following.

We tend to waste our national effort in political disagreement and in futile discussions over ethereal matters of "independence," " anthems " and so forth. *We do not yet realise, as a nation, that our country's most precious material possessions, its vegetation, its soils, its water, are being taken from us by three national foes—Deterioration, Ignorance and Procrastination. As a united nation we must fight these and conquer!*

IV.—Section D: Problems in the Preservation of Wild Animals in South Africa

BY

E. M. Robinson,

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The part of the symposium given to the writer to deal with covers a very wide field and it is not possible to deal with all the headings adequately in the time available. It will be advisable, therefore, to deal with the aspects of the subject with which the writer is most familiar in some detail and to refer briefly to the other ones. The main portion will therefore deal with the subject of diseases of domesticated stock in relation to the preservation of wild animals.

Dealing first of all with the question of vegetation, the burning questions are those of soil erosion and over-stocking. These have their influence on wild animals as they do on domesticated ones. Over most parts of South Africa at the present time game has been destroyed to such an extent that were it not for preservation on certain farms most wild herbivora would have disappeared. Over-stocking, which is the rule on most South African farms, has rendered it impossible to preserve game animals in any numbers and their future lies in attempts to keep herds in reserves or on big farms where the owners are prepared to keep the numbers of their domesticated stock within reasonable limits. Some farmers with ample means, like Mr. Newberry, of Clocolan, have maintained numbers of different species of game animals on their farms. In the more remote parts of the Northern Transvaal herds of wildebeest still exist and numbers of other game species, as the country is not overstocked with cattle but these are naturally dependent on the vegetation and, under drought conditions, they migrate for long distances. In the early days of the European occupation game animals of all species were found in large numbers all over the Transvaal, but their numbers were always limited by the available vegetation and water supplies.

The question of adequate water supplies has always been one of the major problems of game preservation. If suitable water supplies are not available the game will migrate and thus render their preservation difficult. On farms where small herds of animals, such as Koodoo, are preserved as in some parts of the Eastern Province, the animals frequently have their own waterholes from which the cattle on the same farm usually do not drink. This may account for the marked incidence of tuberculosis in some of these koodoo herds, whereas the cattle on the farms are free from it. It has been found necessary in recent years to establish a number of bore holes in certain parts of the Kruger National Park in order to prevent the game dying or migrating to other parts which would then become overstocked, or going out of the Park altogether. The same problem has arisen in the Addo Bush. When the water holes dry up the elephants become a menace to the surrounding farmers.

As a general statement it may be said that it is not possible to farm with domesticated stock and game at the same time if the latter are in large numbers. In parts like the Orange Free State large herds of springbok could be kept without affecting stock like sheep very much—except from the economic aspect in reducing the available grazing, but, as will be seen from the points which will be mentioned under diseases of domesticated animals in relation to wild animals, the preservation of wild animals except in reserves will always be difficult. Certain types of animal such as the wildebeest are a problem in that when frightened they will rush fences and break them, but the real problem is the question of their part as carriers of diseases in domesticated stock.

Of all the problems in the preservation of wild animals in relation to domesticated stock that of nagana or tsetse fly disease must take first place. In the early days of the Transvaal and Natal fly belts existed over large areas. Fuller has made an attempt to define these belts as they once existed, obtaining his information from some of the early journals such as Trichardt's diary and later records. Nagana made it difficult to farm with cattle in or near these belts but with the gradual disappearance of big game animals, it became rarer, and even before the great rinderpest epidemic of 1896 it was limited in its distribution. The rinderpest epidemic by destroying enormous numbers of cattle and large game animals reduced the tsetse flies to such an extent that they subsequently disappeared and the only remaining foci were in the Zululand Game Reserves. An interesting sidelight on the question of the disappearance of the tsetse flies from the Transvaal is the fact that, owing to the successful use of the Harris Trap in Zululand, in those parts of the reserves where intensive trapping has been carried out using a large number of traps, the incidence of the flies has been reduced to such an extent that, although the traps can probably never catch all the flies in any area, when they reach a low concentration, they have a tendency to disappear naturally. Never at any time during the rinderpest were all the possible hosts of the tsetse fly reduced to such small numbers that it was short of food material but it would appear that the fly is largely dependent on certain types of big game animals. For many years now the problem of European cattle farming in the neighbourhood of the Zululand Game Reserves has been a problem and much hardship has resulted from the encouragement of settlements there—particularly some of the post war ones. The position has greatly improved since intensive trapping of flies has been commenced, but only recently an outbreak of nagana has occurred in Northern Natal, which is almost certainly due to tsetse flies emanating from the Reserves probably following migrating koodoo. It is probable that with intensive trapping it will be possible to eradicate tsetse flies from the Zululand Game Reserves, as they constitute islands of infection in a sea of uninfested territory unlike the big fly belts of Rhodesia and Central Africa which, when reduced in one direction, may extend in another.

The existence of a game reserve such as the Kruger National Park embracing large areas which at one time were fly belts does not in itself constitute a menace to the European farms in the neighbourhood as tsetse flies are absent from the Park as far as we know. The proximity of centres of nagana infection in the adjacent Portuguese territory does, however, present a danger, especially if drought conditions there should cause any extensive migration of big game into the Park. Parts of the Park undoubtedly have conditions which would support the existence of tsetse flies and it is to be hoped that it will remain free. We

still do not fully understand the mechanism which controls the disappearance of tsetse flies from certain areas, but the extensive observations of Swynnerton and others are throwing some light on the subject.

Another disease which may present a problem in the preservation of game in the neighbourhood of cattle is snotsiekte, a disease caused by a virus carried by wildebeest. In certain widely separated areas in South Africa snotsiekte used to cause heavy losses in cattle and the association with the wildebeeste, particularly the black one, so common at one time in the Orange Free State, was recognised by farmers. It would appear that all black wildebeeste are not carriers of the infection and it is only when intimate contact of cattle with these animals occurs, as it might under drought conditions or as it did when the wildebeeste existed in countless thousands, that cattle become infected. Once infected, cattle can transmit the disease to other cattle by contact. The blue wildebeest can also act as a carrier of the infection and neither species has actually been noticed as having ever shown any symptoms of the disease. The mechanism of transmission from wildebeeste to cattle in nature is not known but it is thought to be some ecto-parasite such as the louse. At present the disease is of rare occurrence in South Africa, but occasionally, from correspondence with farmers in areas where wildebeeste can come in contact with cattle, we know that small sporadic outbreaks still occur. Snotsiekte does not therefore at present constitute a serious obstacle to preservation of wild game.

A more important condition and an ever present menace is African swine fever. This disease was first described in South Africa by Steyn in 1926 as a result of his investigations into a disease of pigs in the Koedoesrand area of the Waterberg in the Transvaal. This very fatal disease of pigs is apparently the same condition as was described by Montgomery in 1921 as occurring in Kenya.

The mortality from this disease was so great that it rendered pig farming impossible in the localities where it occurred. It was recognised by farmers that the disease broke out when domesticated pigs came in contact with warthog. Montgomery showed that in Kenya both the warthog and bush pig were associated with swine fever in pigs. These two species of wild pig act as carriers of the infection and do not show any symptoms themselves as far as we know. Although the blood of these animals in certain parts of South Africa, particularly the Northern Transvaal, contains the virus causing the disease, it has not been possible to show experimentally that contact of pigs with infected warthogs or bushpigs results in infection. Walker (1933) considers it is probably necessary for transmission to occur by means of an insect vector, possibly a mosquito. When pigs become infected, however, they can then infect other pigs by

contact mainly through ingestion of material contaminated by their urine and, to a lesser extent, by faeces.

From time to time infection from wild to domesticated pigs has occurred in the Northern Transvaal and the infection has then been carried to pigs in other areas through the markets, until the present stringent regulations controlling pig traffic were introduced. There is little doubt that the devastating outbreak of African swine fever in the Western Province in 1935 was due to infection introduced in this way. The African type of swine fever is related to the well known hog cholera of other countries but is a much more virulent disease. It will therefore be seen that successful pig farming in close proximity to warthogs or bush pigs in certain areas of the country is out of the question and is a constant source of danger to the rest of the Union. We do not know to what extent the wild pigs in the various game reserves are infected as no survey has ever been made.

An important question which has been raised several times in recent years is whether game animals play any part in South Africa in the spread of foot and mouth disease. In Southern Rhodesia, where the disease has been present from time to time since 1931, little evidence has been brought forward so far to incriminate game animals as carriers of the infection. In one case of a koodoo which was shot in a foot and mouth area, lesions were found in the feet which were due to the disease but this is an isolated case. All the new outbreaks in Southern Rhodesia could be traced to actual movements of infected cattle, according to Lawrence (1935). In view of the experience in California where deer became infected and the numerous records of infection occurring in various types of deer and other animal species n Europe, one must not be too dogmatic in expressing views on the possible part which game could play in the transmission in South Africa. The virus which is encountered here produces symptoms of a very mild type as a rule, but studies on foot and mouth viruses from various sources have made research workers chary of predicting what variations they may undergo, and we may yet encounter viruses which easily become adapted to game animals of the antelope type.

Although it is relatively unimportant as a source of infection to cattle, one must mention that koodoo and duiker preserved on certain farms in the Eastern Province have suffered severely from tuberculosis of the bovine type and are a possible source of infection to cattle on the farms where they are, though, as has been mentioned earlier, through lack of close contact the cattle do not appear to become infected. A peculiarity of this koodoo tuberculosis is the occurrence of extensive lesions in the throat region, a site where they are not usually prominent in cattle.

All kinds of game animals may die of anthrax on farms and their carcases may be a source of infection for cattle. Cases of

anthrax have occasionally been recorded in antelope species but naturally most of them would go undiagnosed, as smears are rarely taken from game animals dying a natural death.

Recently we have encountered a disease in dogs in the low veld of the Transvaal which may have some association with wild carnivora. It causes a progressive and fatal anaemia in dogs and, so far, no cure has been found for it. The parasite causing it is a rickettsia infecting the blood and it is transmitted by a tick, *R. sanguineus*.

The question of infection of wild game in Reserves or elsewhere in South Africa with the organism of bovine contagious abortion has not yet been investigated but we know that in the American National Parks the disease is common in buffalo and caribou. It is quite possible that it could infect some of the antelope species and one has to bear it in mind.

Two diseases which may be associated with wild animals in South Africa are plague and rabies, but no attempt is likely to be made to preserve their carriers. In a recent report Dr. Fourie of the Health Department has shown what an important part the wild rodents have played in the maintenance of foci of infection since the disease spread to them from rats. The infection of meerkats with rabies has made the eradication of this disease a very difficult problem.

Other problems which have to be considered when dealing with wild animals are those of internal parasites and ticks. A number of the internal parasites of sheep and cattle can maintain themselves in antelope species, but this would not present a problem except on farms where the game animals were too plentiful.

Tick infestation is more important as there are certain diseases of cattle and sheep for which game animals can act as carriers. In others, such as East Coast Fever, the ticks by feeding on antelope species would free themselves from infection as the antelopes are insusceptible.

We know from experimental evidence that the blesbok can act as a carrier of anaplasma, the cause of gallsickness in cattle and also of the viruses of bluetongue and heartwater. In the case of heartwater, the question of wild animals is of more importance, as the disease can be eradicated in domesticated animals by dipping, but the eradication becomes impossible if hosts for the ticks remain, as one cannot of course dip the antelopes.

As regards the distribution and sociology of the natives, it is difficult to know what part they play in the question of game preservation. The native would not preserve game as the white man attempts to and it is fairly certain that if he had had guns he would have exterminated the game as successfully as the pioneers of South Africa have done. I understand that in

certain parts of Portuguese East Africa where the natives have firearms they have very successfully got rid of the game. Under primitive conditions a balance would probably be maintained between the native and the wild game, as it is unlikely that he would destroy more than he could use.

In dealing with the various aspects of the question which I have been asked to I feel that I have devoted most of the space to the discussion of wild game and diseases of domesticated animals but I feel that in this I have been justified as it is the aspect with which I am most familiar. This subject will form the substance of a paper to be presented to the Medical Congress in Lourenco Marques by Dr. G. de Kock, Acting Director of Veterinary Services in September of this year and it will be dealt with there from every point of view and many aspects will be discussed which time prevents me from going into.

V.—Section E: Problems in Protection of Features of Anthropological, Archaeological and Ethnological Interest in Relation to Changes in Native Sociology and General Economics in the Union

BY

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The four previous contributors to this symposium on "Problems in Protection" have dealt with the climatic, geological, vegetational and faunal aspects of our central issue: conservation. It is my task to present the human aspects of conservation from the dynamic standpoints of sociology and economics.

Before launching out on this topic it may be said of conservation in general that its realisation cannot spring Minerva-like fully-equipped from the head of Zeus. It can only arise through a sense of loss first felt by the intelligent few; then, being spread abroad amongst the nation at large, that sense of calamity is finally so generally shared that collective action is taken to avert the lamented loss. Thereafter only can planned and economically-justified conservation result.

Things are counted as lost only when values have been attached to them, i.e. when they have become treasures! Hence the primary business of those, who are sufficiently informed to realise the benefits, physical or mental, attaching to those things which should be preserved, is to make it known to

everyone in intelligible language the values, real or imagined, of the elements under consideration for conservation.

The economic values of plants and of animals are, more or less, patent; they can be bought in shops or yards; we live upon them; so widely are their conservation values appreciated already that departments of forestry and agriculture are devoted to their maintenance by the Government. The fabulous treasures of geology need little emphasis in the mining community; and so closely bound up with agricultural welfare are the interests of climate for a people, to whom meteorology has brought new values in the form of travel and wireless recreation, that it has become almost superfluous to discuss the economic wisdom of studies in climatology.

The values of dry bones, burial customs and stone implements are not so obvious; they savour rather of sickness, death and the charnel-house. Are they useful or beautiful? The loveliness of the skeleton, the sole surviving remains of individuals that once lived and moved and had their being, remains as yet unsung. Yet the art of medicine is reared thereon! The ancient arts and crafts of our forefathers, their habiliments, household furniture and pursuits are suitable themes for pageantry and sophisticated amusement; but the values of these things, apart from the price-marked stinkwood furniture, family jewellery and silverplate of the sale room, are discerned only as a result of education and culture. The informed mind can alone appreciate the symbolism and significance of reconstructing the past of humanity and retaining any and all material aids in rendering the reconstruction real.

If the bones and stones repel us and the broken weapons and shattered potsherds can only be resuscitated by the skilled hands and lovingly backward-looking eye, what shall we say of the intellectual effort and training involved in bringing the populace to appreciate—I dare not say love—the outmoded customs, the long-lost music, the barbaric rituals, the fantastic familial and tribal relationships, the forgotten history, law and religion, in brief the immaterial but sacred things of South Africa's past! For they have human values; they have been handed down in those twin but characteristically human media of the living voice in languages, mythology, tradition and song, and of the vanished hand in carving, painting and fragmentary symbols! Because they are without money and without price, are they without value?

Whatever the values in these several categories of essentially human things, no Government department has burst into existence for their conservation. But I take it as a mark of our collective advancement in appreciating the values attaching to anthropological, archaeological and ethnological pursuits in South Africa that these neglected and despised sciences have been elevated to their present point of participation in our symposium to-day.

Because this intellectual appreciation was virtually non-existent in South Africa, but had been comparatively highly evolved in Europe, in respect of these matters in the centuries following the Renaissance our treasures: anatomical and palaeontological, ethnological and archaeological, even those historical and artistic, have been flowing in a steady stream into collections and museums of Europe and America to enrich even further the staggering heritages of those lands; in the same way as those European heritages have also been enriched by the intellectual spoils of Egypt, Mesopotamia and the Orient Supply follows demand and the aching void of the omnivorous human mind in Europe during the last 600 years has been so vast that the whole world has been ransacked for its satiation When an equal intellectual hunger exists in our land the tide will be reversed here as it has been in America, and to some extent in Australia. We, too, will one day make the four quarters of the world our intellectual tributaries.

The first public signal of an awakening to our loss, and the world's gain was the *Bushman Relics Protection Act*, No. 22 of 1911; its scope was widened in the *Natural and Historical Monuments Act*, No. 6 of 1923; its latest expression, after repealing these two Acts is the *Natural and Historical Monuments, Relics and Antiques Act*, No. 4 of 1934. This Science Association has played, both directly and indirectly, a leading part in the formulation of the public policy embodied in those Acts; it can congratulate itself on the steadily increasing, conceptual width of the terms of those Acts, and also on the establishment of the Bureau of Archaeology. This will soon become an external and tangible witness in perpetuity of the steady and unremitting labours of the Association and its members over a quarter of a century. Henceforth any object found to be aesthetically, historically, archaeologically or scientifically valuable or interesting in South Africa, whether it is a monument, a landscape, a tree, a building, a cave, a relic, a fossil, a drawing, an engraving, or a piece of old furniture can be proclaimed and preserved for posterity. Now we have an Act to prevent treasures going out of the country, we need another Act to encourage the treasures from other countries to come into South Africa.

This process of attracting to our country its necessary anthropological, ethnological, archaeological and historical *pabulum* has also begun. The peculiar genius of Gubbins found expression along those channels. The proper place for the study of South Africa is South Africa! South Africans cannot study South African objects properly unless they have alongside them in South Africa similar or related objects from Central and Northern Africa, from Europe, Asia, America and Australia. To-day the most serious obstacle in investigating skeletons of Bush and Bantu peoples in South Africa is the lack of sufficient skeletons of Pygmies, Negroes, Australians, Indians,

Chinese, Egyptians, and even of Europeans for the purpose of study by comparison in South Africa. But what is true of bones applies equally to stone implements, potsherds, beads, weapons, musical instruments, woven objects, paintings, engravings, in brief to the whole of the material culture of our local peoples. We need comparative collections, museums and libraries!

There are two divergent aspects of the human conservation problem! One, the simpler of the two, is that embodied in the Act, of discovering a valuable or interesting object, of proclaiming it to be such, and of putting it, along with other dead and past old things, in a glass case or the basement dump of a museum. The other, and the more difficult aspect of human conservation, cannot be incorporated in any Act because it is vocal and ephemeral; it is living and changing in front of our eyes. It is the problem of what we should strive to conserve, if anything, of the immaterial things in the living Bushman and Bantu; of their voices, of the achievements of their brains in language, custom, law, religion, sport, music, dancing and community organisation? Should any of these be preserved? Will they be of any use to us or to them? Or, should they be uprooted and destroyed as quickly as possible in this hectic world in their interests as well as our own?

Europeans stand in relation to these folk in a position analogous to that of the more advanced Romans in relation to our Anglo-Teutonic ancestors. Just as our understanding of Northern Europeans, of ourselves, has been enriched by the writings of ancient observers, such as Caesar and Tacitus, concerning our ancestors, so, too, our understanding of the Bushman and the Bantu, who have—like our own ancestors—no capacity to write for themselves, is being, and will be enlarged by the writings of all those who have interested, and are interesting, themselves in the African peoples. Our writers, photographers, artists and film-makers are our best conservators of those elusive human things, which cannot be imprisoned easily in a glass case. But these writers too have to be trained in observation and description; until our University departments of African Life and Languages, and of Bantu Studies, were established, the possibilities in respect of training the personnel necessary to such conservation were badly restricted. The lack of such institutional advantages in their day and generation is what lends its particular merit to the rescue work carried out by Duggan-Cronin in photography, and by the Bleeks, Junod. Jacottet, Bryant and others in writing—chiefly as missionaries.

The actual problems confronting this business of human salvage are stupendous. Von Warmelo's *Preliminary Survey of the Bantu Tribes of South Africa* is a mangnificent, collaborative and government-supported effort, and a landmark in enumerating, classifying and numbering the South African tribes and their present distribution. Incidentally it has displayed

in a most forceful way the sad lacunae in our knowledge of these people. He found the data so bare that the classification of the Bantu on purely historical grounds was out of the question, and that one based on ethnological or cultural grounds, however desirable, was impracticable because "the published information on custom is conspicuously full of gaps, one-sided, scanty and inadequate when it comes to attempting a complete classification of the South African tribes. One could name scores of tribes from which our museums have neither a pot nor a spoon, nor the smallest object of any description whatever, and about whose customs and laws not so much as a single word has ever been put on record."

This sweeping reproach will, we trust, be removed in the course of time, but how formidable the work before us! The Natal Nguni peoples, as the same author tells us, are divided into more than two hundred independent tribes, and the Swazi proper include fifty odd tribes. Similar diversity characterises the three divisions of the Shangana-Tonga group, the three divisions of the Sotho group, the Tswana group, and to a lesser extent the Venda group and Lemba group. Meantime, we have forgotten the Bushman and discussed only the south-eastern zone of Southern Bantu, and have scarcely migrated out of the Union in our discussion of tribal names and numbers. There is salvage work here for a hundred and more highly skilled ethnologists and linguists in collecting material cultural objects, in recording vocabularies, texts, tribal histories, mythologies, hymnologies, and so forth for a generation to come. Equally we must interest ourselves in the tribes belonging to the other two zones of the Southern Bantu, namely, the south-central zone, comprising the Shona tribes of Rhodesia, and the western zone, embracing the Ambo, Herero and Mbundu peoples of South-West Africa and Angola.

South Africa has travelled, during the last couple of decades, a considerable distance from that naive simplicity of outlook, which regarded the natives as so many "kaffirs," fit only for a permanent servitude to the agricultural and industrial destinies of the territory. She is bound to advance still further during the next three decades in conceptual outlook concerning human conservation. Politically the policy of segregation being adopted in both the Union and Rhodesia as well as further north, is of great value to human conservation; it represents a break with the traditional practice of Europeanising the native and of destroying, by neglect, most of what was valuable and otherwise in the native's own culture heritage.

Drawn by an inevitable chain of circumstances into the economic life of the country, whether as members of their local kraals or as labourers on farms or in mines, in houses or in industries, the native population is none the less caught up in the same tream of life as ourselves. Their segregation is but partial; ıey may be separated physically, but cannot be isolated

economically or psychologically. They may even be segregated from certain types of labour, by exclusion from skilled jobs and authoritative posts; but they constitute and will remain for a long period, the labourers of the community.

There is an ignorant type of individual abroad, reminiscent of the courtiers of King Canute, who bids our present European-Native situation sit royally where it rests, despite the rising sea; or, ostrich-like, buries its head in the sand so that himself unseeing, he imagines all problems as non-existent. Human relationships are not static but dynamic; they move, have moved, and will continue moving.

We have taken from the natives for the most part their chiefs, their system of law and justice, their ritual and religion, their arts and crafts, their clothing and education, their ideas of morality and etiquette. All of these flowed from their concepts, innate or introduced in ancient times, of what constituted beauty and propriety in life, the business of living.

When Rome had subdued the Mediterranean basin, and was substituting Roman law, language and culture for their local counterparts throughout this domain, the Emperor Augustus was faced with a similar problem. According to Buchan (Lord Tweedsmuir) he approached it with an idea, a point of view. " His conception was of a gigantic client-state, an asset, and also a responsibility. He would give it peace, security, law self-respect, and a decent freedom, but always it must take second place to Rome."

Under our changing economic and sociological circumstances the issue before the conserver is not " what ought we to conserve? " but rather " what can we appropriately conserve? " Before the relentless march of the trader little remains of the clothing and personal adornment of our native tribes, even in their kraals! The cheapened mass production of household utensils, building materials and farming implements inevitably destroyes practically all native, pre-European, mental achievement in craftsmanship and art. Here we find ourselves, Augustus-like, suggesting no panacea but an *attitude*, a technique. Surely in these fields the business of the conservator is not that of resisting the flood by hanging on to the old, but of preserving and transmuting the old mental concepts of beauty and propriety amidst the changing material environment?

It may be a trifling example and of accidental rather than planned occurrence, but the mine-compound has achieved something of this beauty and propriety in the preservation of native dancing. I suggest that, even if unwitting, the mine companies have achieved something of beauty and decorum in the changing material environment of our population; and that their achievements towards encouraging this measure of self-respect are not shared by all our municipal councils when they plan native compounds, locations and townships, nor by all

our industrialists and farmers, when they design native quarters. What provision is made there for the conservation and re-creation of native festive occasions; the central ceremonies associated with birth, puberty, marriage and death, to say nothing of their communal dancing and music and their national festivals of first-fruits and the like? Is there nothing here of living beauty, dignity and propriety to be preserved or, if not preserved, *transformed*, or replaced?

The South African native is essentially a social, communal being. Whether we consider on the one hand the polygamous kraal, the sub-district, district or the tribal territory; or contemplate on the other the family, lineage, clan or tribe; or analyse still further the groupings posed on sex, age, ritual or military bases, we are confronted throughout by traditional and virtually instinctive capacity for community organisation, community recreation and community effort. Do a club-room, a beer-hall, a sports ground and a library, even when these happen to be available, represent the climax of their ability, and ours to seize upon and without undue expense, to *transfigure* these inherent potentialities in their common tribal evolution?

It is not my function here to outline remedies but to face these problems with you, and to suggest a point of view. The essential problem in human conservation in South Africa, as I see it, is to find enough people of adequate leisure to study the material, social and spiritual cultures of our peoples, to record therein what is changing, and yet can be conserved, and to plan within the bounds of a rational economy its means of conservation and transfiguration; in other words, we need *ideal conservators*.

In our kindergartens and schools stand to-day the conservators of to-morrow. Their teachers cannot evoke from these infant minds an appreciation of, much less and ardent love for, the anthropological, archaelogical, ethnological and sociological treasures of this country unless those who recognise the treasures can communicate that recognition to the educationalist. This central problem of creating and communicating such values, as lead automatically to conservation, i.e. the place of education and educationalists in conservation—doubtless, forms the theme of my successor in this symposium. I content myself with urging its critical importance in estimating human values and evoking their conservation.

VI.—Section F: Education—European and Native—in Relation to the Problems of Deterioration and Conservation of Natural Resources and Features of Scientific Interest in South Africa

BY

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What can *education* do about the conservation of our natural resources? This is the question I have to deal with. In a sense all of what has been said to-day was directly or indirectly educational because in nearly every instance the problems definitely had a human bearing. All the questions boiled down ultimately to the following: What effect do they have on *man*? or, What is *man* going to do about them?

Education deals with changes made in human beings—changes in a definite direction which is regarded as desirable.

The conservation of our natural resources has value only in so far as it has a desirable effect upon human beings. Take the poor white problem, for instance. This is nothing else than the human side of the problem of the ill-use and destruction of our natural resources particularly in agriculture. The material side and the social or human side are like two sides of a medal. If you look at it from the one side you have such phenomena as drought, soil erosion, stock diseases, etc. If you look at it from the other side you have poor whiteism, i.e., the result, in human terms, of these natural processes.

If you ask me what has this got to do with education I would reply: Everything. I regard a poor white not merely as a person who is *materially* poor, but as someone who also has, in addition to his economic poverty, *a mental attitude* which prevents him from rehabilitating himself or others from helping him to rise above that economic level which we regard as *poor*.

The trouble, therefore, with the poor white is twofold: (a) economic and (b) psychological. And it is chiefly in respect of the second that education can make its contribution. Education can give information, it can cultivate knowledge of *facts* which it is necessary to know, in order to conserve our natural resources. Above all, however, its function is to build up *mental attitudes and habits*.

I stress this latter aspect here particularly because *social tradition* is the overt crystallisation of mental attitudes and habits of the group. Take the practice of the subdivision of farms. To divide up a farm equally amongst offspring rather than leaving

it all for the eldest is a matter of social tradition in South Africa —particularly amongst the pioneer Dutch settlers of the country. Most of the evils of overstocking, of plundering the soil, i.e., only taking out and not putting anything back, and our man-made droughts can be traced to this tradition. Let me say at once, however, that subdivision of farms is not a bad thing, *per se*, provided there is concomitant change of farming methods. That is, after all, the only way in which intensive farming can become possible. Subdivision is, however, disastrous if the sons continue to farm with the same extensive methods that their grandfathers used. An example occurs to me now of a single farm, Rietfontein, a beautiful farm originally of about 5,000 morgen—which was not only ruined as a productive unit but it had produced in four generations no less than 100 poor whites. I was talking to one of those who was still left on the farm. There he sat on 20 morgen of land along the river front and was complaining bitterly of the low price of mealies. I asked him what he intended doing with his portion when he died. He told me he was going to divide it amongst his five children, i.e., each would get four morgen. " But surely," I asked, " how can you expect each of them to live on four morgen when you can barely make a living on 20 morgen?" " Yes, but you see," he said, " Elkeen moet sy sitplekkie hê." (Each one must have a little place to sit on). " Yes," I said, " and I suppose all he'll do is to *sit*!" When I suggested to him: " Wouldn't it have been better if this beautiful farm had been left as a whole to the eldest, as is the custom in other countries, like England, for example?" " Oh no!" he replied, " that would be most unjust." In spite of my arguments he could not see that by this method the farm at any rate would have been conserved as an economical productive unit. This is what I mean by a mental attitude which must be attacked before we can achieve any progress in the conservation of our natural resources. What is worse is the human loss. Because growing up under this tradition each boy, instead of as a matter of course thinking of another occupation or of getting out to seek pastures new, keeps his eyes glued upon the little piece of land he is inevitably going to inherit, and when things go badly with him later on he does not realise that the whole system is wrong, but blames the weather or the government for his misfortune.

This is only one illustration of the role which mental attitude plays. There are others, e.g., the dependence upon inefficient native labour and the unconscious imitation of the native's methods, but I have no time to go into these here now.

The question is what can education do? Here we have a big educational system costing the country £10 million a year on schools. What can the schools do? Let me mention a few things.

1. The general level of our country's education should be raised. When I was engaged in the *Carnegie Poor White Investigation*, I found that 58 per cent. of our farmers had not even

passed Standard VI, i.e., had not completed a primary education. Moreover, 95 per cent. of them had not received any *ad hoc* agricultural training whatsoever. To think that it is to people with such a low level of training and development that we have entrusted the conservation of the most precious of our natural resources in South Africa, viz., the top inch of soil, which is a greater asset to our country (though people do not always realise it) than the gold buried thousands of feet below!

To think that we have entrusted probably the most difficult of occupations, viz., farming, to people so badly trained for that work! In no other occupation will we risk that. No wonder that the farming population has been most prolific in producing poor whites.

2 More attention should be given to these problems in the primary school. We must catch them young. It is our only chance. The vast majority never get into the high school, and less than 1½ per cent. ever pass matriculation.

On going through the primary and secondary syllabuses of the schools in the four provinces I was struck by the scanty reference made to the problems with which we are dealing to-day. In most syllabuses the words "soil erosion" are mentioned in connection with the agricultural course. The general attitude is, however, more one of "successful exploitation" than of the conservation or preservation of a *trust* held for future generations. Though a love and admiration of nature is mentioned in the nature study syllabus of one province, no mention is made anywhere of conserving fauna, flora, etc., or of monuments and archaeological treasures, etc., for the future.

3. What one puts into a syllabus, however, is of very little avail if the *teacher* is not there to fuse these scattered items into a functional whole and to inspire youngsters with enthusiasm for them. Many teachers unfortunately lack the life experience to see the significance of these problems. Still, a good deal can and should be done during their course of training to interest them in these matters. I would suggest that in every training college in the country one whole week should be devoted to these topics, and that missionaries like Professor John Phillips be engaged by these colleges to give a short unit course of lectures. By his eloquence and contagious enthusiasm I am sure he will interest our future teachers in these problems and help them to correlate these with the ordinary school work. After all, it is the teacher that makes the school.

4. A number of these teachers become farmers' wives, and as such can be forces of influence on the spot. I do not think that people have ever adequately realised the powerful role that the womenfolk — mothers and housewives — can play in this matter. *Women's clubs*, as well as *boys'* and *girls' clubs*, can do much towards this attitude building business. The Women's

Agricultural Union is already doing a great work, and could do still more in this direction, if the matter is properly put before them.

5. In this connection let me mention *school museums*. Here we have a grand opportunity of interesting young people in the archaeological wealth of our country, for the preservation of which Professor Dart made such an eloquent plea in his paper this morning. Just think of the attitude of curiosity with which youngsters will climb rocks and play in the river banks when they know the significance of arrow heads, flints and other implements of primitive cultures, not to mention drawings, etc., if they could have had an intelligent interest awakened through the school museum.

6. The *Radio* is a great instrument of adult as well as juvenile instruction in these matters and should be used in a systematic way to bring these points home to people. Time does not allow me to develop this point more fully.

7. Lastly, I would like to mention what seems to me to be by far the most powerful single instrument through which public conscience can be awakened with regard to the conservation of our natural resources, and that is the *film*. While I do not exclude the methods by which one can subtly build up public opinion by suitable films in the regular public cinema houses, I have in mind particularly the use of the 16 m.m. film in the schools, in community clubs in rural areas, Native as well as European. Space does not allow me to describe to you some of the excellent films which were made in Tanganyika for Natives. using natives as actors, in the Vugiri Cinema Experiment financed by the Carnegie Corporation and directed by the International Missionary Council. For example one film shows that to listen to the agricultural demonstrator *pays better* than to follow their traditional methods of doctoring lands. By utilising drama one can play upon the two fundamental drives in human nature, e.g., the food-getting and the sex instincts, and thus the film becomes a potent educative force in breaking down superstition. As the Chinese put it: "One seeing is worth more than a hundred tellings."

The Film Division of the National Bureau of Educational and Social Research has over 1,000 films of the 16 m.m. type in circulation in South African schools. While we have already some good films on the natural sciences, e.g., geology, etc., the subjects deal with natural phenomena in other countries. I am particularly desirous that we should make films with our own country's phenomena, e.g., we have dongas as fine as any in the world! Right here I want to issue an invitation to those of you interested in the problem of soil erosion to submit to me suitable scenarios for instructional films on that subject. I suggest that a start with two films be made. The one is to be purely physiographic, dealing with the physical effects of water and wind on soil. By means of moving diagrams and photos we can

try to show graphically, e.g., how much 32 million tons of silt is which Professor Alex. du Toit spoke about this morning. I don't know whether you have, but I have no concrete idea how much or how little this amount of silt is which the Orange River is supposed to take down to the sea every year. This film is to deal with such scientific facts in a graphic way. The other film is to deal more with the sociological and economic implications of soil erosion, and incidentally with preventitive and conservation methods.

These films should be made as simple as possible so that they can be used also in native areas. They should be films sounded in the native vernaculars as well as in the official languages. 16 m.m. sound projectors cost from £60 up, and can be carried in two suitcases in an ordinary car. With their own generators of electricity they run to about £100 complete. If fixed on light trucks you can take them and show pictures in the most remote corners of the country.

While taking for granted the good that the ordinary school can do for the education of natives, I wish to stress this new instrument of education because of its great possibilities in reaching the illiterate masses of the native people. More than five times as many natives as white people have to make a living on the land. Their areas are becoming more and more over-crowded, and the motive for exploiting the natural resources of the country becomes with them more and more a matter of life and death. Remember that to them as much as to the white man is entrusted the conservation of our country's natural resources. In fact, they occupy some of the best parts of South Africa as far as good soil and regular rainfall is concerned. A mere glance at what is happening to-day in Basutoland and in the north-eastern parts of the Cape will convince anyone of the seriousness of the losses which South Africa suffers annually by denudation and erosion. When I blame the native I do not thereby wish to exculpate the European. On the contrary. We as white people having greater privileges as regards general enlightenment are responsible not only for our own areas but also to help the native to conserve this country's natural resources, which is the common heritage of future generations. We are all, black and white, in the same boat, as the economic interests of both are becoming more and more interlocked.

In conclusion let me mention two points.

(1) The chief objective of all these educational measures suggested above should be the cultivation of a sense of *individual responsibility* amongst all members of the community towards our natural resources. If every individual farmer, for example, plays the game on the spot, then and then only will we win out in the end. Government action is of little avail, unless every member of our society, both black and white, does his share of conservation on the spot.

Moreover, I feel that if we start early enough in the schools we shall (even though children may forget the facts imparted) at least succeed in creating in the minds of the coming generation a more receptive attitude towards ideas concerning the conservation of our natural resources. Such an attitude will lay the foundation for whatever measures of adult education may be resorted to in the future, e.g. through agricultural extension services, the radio and the Press.

(2) Remember that the conservation of natural resources is not an end in itself. These resources have no value apart from their significance for *man*. Man, living man, is what matters ultimately. Imagine this world of ours with all human beings suddenly removed from it. There will be rivers, mountains, fields, but no one to exploit them. There will be books, buildings, bridges and ships, etc. But no one to use them. All these artifacts of man will be merely relics of no value, because there will be no one to value them. I mention this to show that the conservation of our material resources is of no avail if man is lost. The big and ultimate problem, therefore, becomes the conservation of our human resources. This might well become the theme for another symposium.

The emphasis must be on *man*, not only as the ultimate source or criterion of value but also as an active controlling power. I noticed in some of the papers this morning that the word "adaptation" was often used with reference to man in relation to his environment in this country. This concept of adaptation has its limits. When applied to man it is not very satisfactory, because it treats man too much as merely a passive object being pushed hither and thither by material forces. No, man is or rather ought to be something more. I prefer to look upon him as a consciously planning agent. He not merely adapts himself to his environment, but he also adapts his environment to himself, his own ideas and his aspirations.

It is his prerogative to harness and to control those natural forces. The trouble about the poor white, for example, is the fact that he is too much a passive victim rather than a controlling agent of his environment. It is to this *active* principle in man by which he constantly seeks to *control his environment* that we must look if we wish to achieve progress. This is the antithesis of passive adaptation, of taking the line of least resistance, of the domination of matter over spirit — all of which spell degeneration in the long run.

The function of education is to cultivate and to guide this *active* principle which is man's sole guarantee for survival.

THE SUMMING UP

BY

THE PRESIDENT (Professor L. F. MAINGARD).

It is right that I should, first of all, express our thanks to Professor John Phillips, to whose organising ability and broad vision we are indebted for this symposium, and to those distinguished members of the Association who have each contributed a paper for his respective section and, finally, to those who, by taking part in the discussion, have added to the value of our proceedings to-day. It has been, I think we can say so now, an unqualified success. It has proved that there are no watertight compartments in life and it has stressed the usefulness of team-work in scientific investigation. I submit to you that even if this symposium has achieved nothing but this, it has given something extremely valuable.

You have heard the views of the different contributors. I do not consider it necessary to go into technical details at this stage. I think a better purpose will be served by bringing the salient points into bolder relief and by extracting from the papers and the discussions the general ideas which they contain. In this way we shall get a clear view of the position, of the trend of our scientific thought on the question which is occupying us, and of the real significance of this symposium.

On glancing at the titles of the papers and remembering their contents, we can see that they fall into two main groups, the one dealing with the more material aspects of our subject and the other more concerned with the intellectual background of the problem. Let us consider the first group.

Professor Plummer and Dr. Haylett have presented the results of their study of our climate. You have seen the very great importance played by solar radiation in these problems, so far as our knowledge goes. We, in the Union, are privileged or otherwise in having a greater amount of solar radiation than any other part of the world. A good deal of investigation still remains to be done before we are fully informed. But this is only one side of our climatological position, fundamental though it is. Rainfall is also all-important and, in our case, it is notoriously irregular, unreliable and insufficient. The characteristics of these two features of our climate are largely responsible for the soil erosion which is going on in this country.

But it is not the only factor in the problem of soil erosion, as Dr. du Toit has pointed out this morning. There is the very geological composition of our soils, deforestation and overgrazing to be taken into account to explain the losses which our land surface suffers every year. He has calculated that in 1926 the astounding amount of over fifty million tons of soil was carried off from the basins of the Vaal and Orange Rivers alone.

This picture is gloomy enough, but the facts brought forward by Professor John Phillips make it still blacker. His comparison of the vegetation of the present with that of former days shows a general deterioration, whether we look at our forests, our grass-lands or at the Karoo. Man, both black and white, has been at work, with fire, axe or overgrazing. The face of the earth has profoundly changed within the memory of man, and the steady reduction of the vegetal covering is effectively helping soil erosion.

The dangers confronting us are grave and pressing. What is the remedy? Dr. du Toit advocates the creation by the Government of a special reclamation service. Professor Phillips, after paying a well-deserved tribute to the work of the Forestry Department and to the Division of Plant Industry, sees salvation in more vigorous Government action, but more especially in greater co-operation between departments and with the Universities and the use of films, broadcasting and other educational methods. We shall revert to this later on.

We now come to Dr. Robinson's paper. He spoke chiefly of the diseases of wild animals as a possible source of infection to domesticated stock, a matter of vital importance when we consider the question of preservation. He has given us some useful information. But let me add some personal observations and remind you of the countless herds of wild game, chiefly antelopes, which roamed over the plains of the Union, in some parts, as late as the middle of the last century, as we are told by our old travellers and hunters. These have almost entirely disappeared before the progress of European settlement. Indeed, some species, like the quagga, are as totally extinct as the fossilized fauna of the ancient geological beds of the Karoo. Perhaps, I may venture to say, their disappearance is to be explained, apart from the indiscriminate slaughter of the early days, by the fact that, in our present-day system, they are regarded as of less economic value than domesticated stock, as is proved, for instance, by the organised destruction of a large number of our wild animals in an outbreak of nagana in Zululand not so long ago.

Similarly, ethnological features of native life and our archæological and anthropological treasures are to be assessed not in terms of economic values, but rather of scientific, cultural or "human" values, as Professor Dart puts it. Because of their nature, they were once neglected. One interesting remark of Professor Dart that the ethnology of our native population may be partially salvaged by our policy of segregation is worthy of note. I do not, however, believe that the salvage can be of a permanent character. Under the influence of European contacts which cannot be entirely eliminated, much of the older features of native life are bound to disappear. Our pressing duty is to put on record as much as is possible before the fateful hour comes.

A good deal, however, has been accomplished here. The question of the preservation of wild animals, especially the larger mammals, has been rightly tackled by the National Parks Board, and we now have the Kruger National Park and similar reserves, on a smaller scale, in other parts of the Union. Nor should we forget the useful work of the Provincial Administration in Natal. In the matter of historical monuments and relics, which include our anthropological and archæological wealth, the Historical Monuments Commission, with its recently enlarged powers, is making rapid strides towards recapturing and conserving all that which links us up with our historic and pre-historic past. The Bureau of Archæology has also made notable contributions in this direction.

Dr. Malherbe, as an educationist, agrees, and rightly so, with the educational policies of Professor Phillips and Professor Dart. He has convincingly pointed out that poor whiteism is only another facet of poor agricultural conditions, and that poor agricultural conditions, in their turn, breed poor whiteism, and this vicious circle is aggravated by the very low educational standard of the majority of our rural population. He believes that, through our schools and training colleges, through films and broadcasting, we can sow the seeds of future improvement. The corrective is obviously better education, and his advice is: "Catch them young."

The discussion which has followed has been very remarkable, both by the number of those taking part and the suggestions made. I shall also adopt the same procedure as in the case of the papers. I shall endeavour to retain only the general ideas expressed by the speakers and to group together those of a similar import.

In the first place, I should emphasise the very general degree of agreement among the speakers about the wastage of our national resources and the necessity of prompt action in order to stop it. Dr. Bush, for instance, supported the idea of a closer co-operation of the Government departments as a corrective, while Dr. Fisher, of Cedara, again stressed the importance of education, more especially agricultural education. Professor Smith also added his contribution in the same direction. The plea was put forward by Dr. Henkel that we, as an Association, should strongly urge a detailed survey of the animals of the Union and the vegetation on which they live. To this, Dr. E. P. Phillips answered that we had surveys of different sorts as well as pasture and veld reserves.

Mr. Hall, however, pointed out that a large number of farmers were taking advantage of soil erosion schemes, and that the Provincial Administration were generally using contour drainage to combat it. Professor Phillips, I suspect, would answer that all this, good as it is, is a mere drop in the ocean, and that the unprogressive farmer is doing nothing to save our soils and vegetation.

Professor van Riet Lowe remarked very aptly on the fundamental position of climate in all our problems. His view is that we should readjust ourselves, and he contended that degeneration had in the past resulted from climatic conditions. Dr. Robinson agreed that man and beast tended to degenerate in South Africa, but on second thoughts he queried the word "degeneration." Should we not rather speak of "adaptation"? He referred to nutritional problems, and asked whether the Bushman was a degenerate or whether he had merely adapted himself to his environment.

Very strong criticism of the nature of the topics discussed came from Mr. Justice Krause, Miss H. Pollak and Dr. Boehmke. They expressed disappointment that a place had not been found in the symposium for a discussion on the conservation of human resources. Speaking on human deterioration, Miss Pollak said that infant mortality, a declining birth-rate, and malnutrition demanded our attention, and that demography had not even been mentioned. Dr. Krause felt that something was missing in the discussion. He was impressed by the absence of the sociological sciences.

The answer is that it was not the intention of the organisers to cover so wide a field, although they are fully aware of the vital importance of the human material in their problems. Of this truth we have evidence in the mention of poor whiteism, and on the insistence on the role of education. I personally am glad that this criticism was forthcoming, as, once more, it lends support to my former contentions, and shows that we are becoming more and more fully alive to the inter-relation of all these different threads in the great pattern of life.

I should like to conclude with this reflection that, while studying the problems of climate and soil erosion or those of the preservation of wild animals or of our archæological and anthropological treasures, we were really dealing with man's environment and man's environment as conditioning human problems such as those raised by Mr. Justice Krause and his group. For it must not be overlooked that science has no existence apart from man, and that, therefore, the ultimate aim of science is man.

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